N.M. Eagler

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BULLETIN
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American Association *of* Petroleum Geologists

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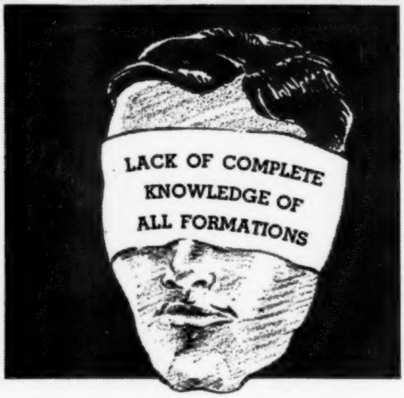

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BULLETIN
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OCTOBER, 1936

PRINCIPAL PHYSIOGRAPHIC PROVINCES OF MEXICO[1]

EZEQUIEL ORDOÑEZ[2]
Mexico City, Mexico

ABSTRACT

The writer outlines the principal characteristics of the physiographic provinces of Mexico, using in general what has been published in the vast geologic and mining literature on the country, supplemented with his personal observations. He expresses the idea that several of the physiographic units should be subdivided into several more sub-provinces, but data are not available to establish proper boundaries.

Certain areas, as for instance the Gulf Coast sub-provinces, should be described with more detail, in view of their economic importance, but much information was omitted in order to retain uniformity in the description of each province.

The writer thinks that some of his statements may be too advanced, considering the present available information or his incomplete personal observations; thus, these points may be subjected to criticism.

The so-called Province of the Valley of Oaxaca seems too small to mention with the much larger physiographic provinces, but its location and characteristics justify its consideration in the general scheme.

The boundaries of each province may not be entirely correct, especially when traced on a large-scale map of Mexico, because of the many natural irregularities of the boundary line of each province and the gradual merging of one into another.

INTRODUCTION

The object of this paper is to outline the principal physiographic provinces of Mexico and to discuss briefly their outstanding characteristics. Mexico is a very mountainous country with areas of high relief occupying at least three-fifths of its total area. A few of its physiographic provinces are only extensions of similar physiographic

[1] Read before the Association at the mid-year meeting, in Mexico City, October 16, 1935. Manuscript received, February 24, 1936.

[2] Abraham Gonzales 79. The writer offers his thanks to L. Ridings and Ed. Borrego for their valuable assistance in preparing the English translation and to W. G. Kane for the final correction of the manuscript.

provinces of the western part of the United States and follow the same general trend and pattern of high relief. There are, however, physiographic provinces in Mexico which have no direct connection with the adjoining part of the United States.

In the northern and broader part of Mexico, the elongation of the physiographic units is northwest and southeast, following the general trend of the North American Cordilleras. Farther south toward the Isthmus of Tehuantepec, their general elongation changes to west-northwest and east-southeast, in harmony with the shape of the continental mass.

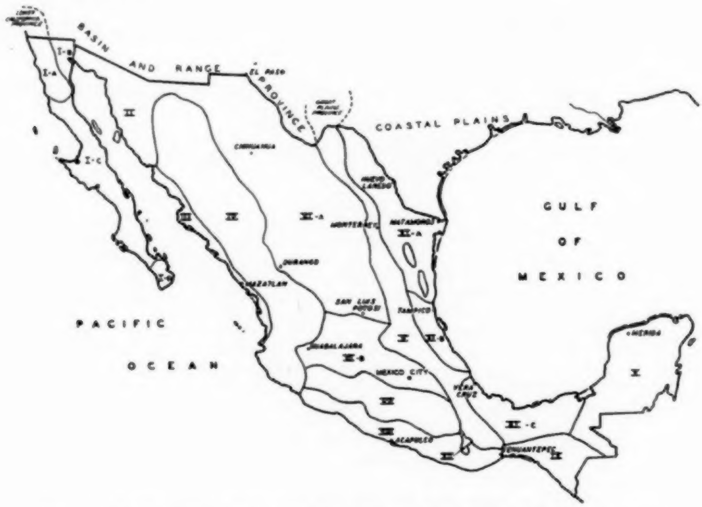

FIG. 1.—Outline map of Mexico showing principal physiographic provinces.

The Isthmus of Tehuantepec, which has a width of only 160 miles from the Gulf of Mexico to the Pacific Ocean, represents the south end of the North American continent and forms the Isthmian link between North America and Central America, of which the Mexican states of Tabasco, Chiapas, Campeche, and Yucatan, and the territory of Quintana Roo form the northern part.

Due to the natural difficulties, such as extensive tropical forests, wide tracts of desert land, lack of population, and limited transportation facilities, data for a more accurate demarcation of physiographic provinces is not available at this time. Since this paper deals only with some of the more general characteristics of the main physiographic provinces, it should be borne in mind that this work is intended to be rather elementary in nature.

Provinces

The principal physiographic provinces of Mexico are shown in Figure 1 and are discussed under the following heads.

I. Lower California
   A. Ensenada Sub-Province
   B. Colorado Delta
   C. Peninsula
   D. Cape Region
II. Sonora Desert
III. Coastal Strip of Sinaloa and Nayarit
IV. Western Sierra Madre
V. Eastern Sierra Madre
VI. Central Plateau (Mesa Central Mexicana)
   A. North-Central Plateau
   B. South-Central Plateau (Mesa Central de Mexico)
VII. Balsas Basin
VIII. Southern Sierra Madre
IX. Chiapas Province
X. Yucatan Peninsula
XI. Gulf Coastal Plain
   A. Rio Grande Embayment
   B. Tampico Embayment
   C. Isthmus of Tehuantepec
XII. Valley of Oaxaca

I. LOWER CALIFORNIA

On account of its climate and peculiar geological conditions, the Lower California Peninsula forms one separate province which, because of the varying characteristics within it, has been subdivided into four sub-provinces which are here discussed separately.

A. ENSENADA SUB-PROVINCE

This northern sub-province is similar to the San Diego Province of California with its mountainous area flanking the Pacific Coast. Two long mountain ranges parallel the Gulf of California coast and extend southward through this sub-province. They are known as the Sierra de Juarez and the Sierra de San Pedro Martir. They are very similar in appearance to the San Jacinto and Santa Ana mountains across the border in the United States and may be considered a southerly continuation of them. The Sierra de Juarez and the Sierra de San Pedro Martir are composed of granites, crystalline schists, and metamorphosed limestones, and, as a rule, have gentle slopes on the west and steep flanks on the east. These mountains are separated by a broad, high valley called La Trinidad. Along the summit of the Sierra de Juarez, there are extensive high plateaus while a series of high peaks form the crest of the Sierra de San Pedro Martir.

In the Tertiary and Cretaceous formations bordering the Pacific Coast, several well marked marine terraces indicate the same recent uplift which is characteristic of all Lower California. Due to relatively

recent erosion and conditions in local areas, two and in places three or more terraces mark different stages of this uplift. On the eastern slope of the ranges, facing the Gulf of California, the uplift is very well marked in places by high fault scarps.

In this part of northern Lower California, it rains more than in the rest of the peninsula and, therefore, the slopes and summits of the mountains, especially on the west, are covered with trees and patches of grazing lands. There are several springs of fresh artesian water and a few small permanent streams. Within this sub-province, on the Pacific side, lies the Todos Santos Bay and the town of Ensenada. This bay and the lands surrounding it are noted for mildness of climate; it is believed to be the most pleasant climate at sea-level found in Mexico.

B. COLORADO DELTA

The Colorado River empties into the Gulf of California at that point where the Lower California Peninsula joins the continental mass and forms an extensive flood plain, over which its distributaries run in everchanging channels. From the international boundary line to the mouth of the river, the network of streams is well contained within a triangular area that is limited on the west by a long, high mountain range, the Sierra de los Cucupahs. This mountain extends northwest and southeast and a southeasterly continuation of it is another mountain group comprising the Sierra Pinta and the Sierra de Tinajas. The triangular flood plain is limited on the east by a row of low sandstone mesas at the foot of which the main stream usually runs. There is a contrast between the actual delta flood plain with its flat uniform surface of fertile soil of silty and sandy clays and the extremely dry lands of the low, barren area farther east on the border of the Sonora Desert.

This small triangular-shaped area of the actual delta, however, is only a part of the Colorado Delta Sub-Province, for west of the Cucupahs Mountains a large valley extends from the foot of that sierra to the east escarpment of the Sierra de Juarez. This valley is a part of the Colorado flood plain and is occupied by a narrow, shallow lake, the Laguna Salada, which is fed in time of floods by a distributary of the river. The area between the actual mouth of the river and the west shore line of the Gulf, as far as the foot hills of the San Pedro Martir Mountains, was also an extension of this flood plain which is now entirely dry and barren.

Near the middle of the Colorado flood plain, a lagoon has been formed in a small depression where some of the tributaries discharge their waters. Several outlets from this lagoon join to form a large

stream which eventually empties into the Gulf. This lagoon is called the Laguna de los Valcanes, because of the number of mud volcanoes and hot springs along its western margin.

In this area, the boundary between Mexico and the United States extends east and west and passes a short distance south of the Salton Sea and the Imperial Valley. This curious depression known as the Salton Sea lies 273 feet below sea-level. American geographers consider it to be part of the original bed of the Gulf of California cut off by an alluvial fan formed by the Colorado River, which afterward emptied into the Gulf farther south.

The canals, ditches, *et cetera*, which have been made to divert water into the Imperial Valley of California for irrigation purposes, have greatly modified the natural course of the distributaries of the river. Greater changes may be expected now that the Boulder Dam is completed.

C. PENINSULA

The main province of the Peninsula, which extends over 7° of latitude, is characterized by the extreme dryness of its climate, by its exotic vegetation, and by the nature of its sedimentary rocks which range from Cretaceous to Pleistocene in age. The Pliocene and Pleistocene sediments are principally of volcanic composition. The older Tertiary beds are gently folded, while the thick younger strata lie in the form of elongate, high, inclined mesas cut by numerous ravines. The inclination of the mesas is toward the Pacific Ocean so that the highest crests lie along the Gulf of California, where long, high, fault scarps dip precipitously into the waters of the Gulf. This is especially true of the central part of the Peninsula, where the group of high volcanoes of Las Virgenes and the elongate crest of La Giganta tower above the general level of the mesas. Most of the mesas are or have been covered by extensive flows of basaltic lavas and some lavas from Las Virgenes volcano are evidently of very recent age. A few large granitic masses are also found.

The Sebastian Vizcaino Bay is an embayment between isolated coastal mountain ranges composed mainly of volcanic and intrusive rocks. The embayment area extends inland to form flat, sandy desert basins such as Llanos de Berrendo and Llanos de Santa Clara, over a width of about 220 miles. Large salt lagoons occupy the centers of these basins. Another large desert plain known as Llanos de Hiray extends eastward from Magdalena Bay.

This enormous peninsular territory of Mexico still appears entirely like virgin land, waiting the development of its natural resources, chiefly in mining, agriculture, and cattle raising. While most of this

area is very dry and hot, occasional torrential rains flood the plains and the interior valleys. In this middle sub-province, on the Pacific side, it is very hot during the day, but the nights are fresh and misty. The widest part of the Peninsula, toward Latitude 28°, from Point Gabriel on the Gulf to Point Eugenia at the western end of Vizcaino Bay, on the Pacific, measures 140 miles; the narrowest part near La Paz has a width of only 25 miles. The Lower California Peninsula is the least inhabited part of the Mexican Republic.

D. CAPE REGION

Geological characteristics similar to those of the Ensenada Sub-Province are seen in the small sub-province of El Cabo, at the southern end of the peninsula. A group of granitic mountains occupies the larger part of the area, but on the eastern side some Tertiary rocks appear. Isolated, small, rock masses emerge from the waters at the southern extremity of the San Lucas Cape. Successive marine terraces are found on the Pacific side and since similar terraces border this coast throughout the whole peninsula, we must conclude that this entire territory has undergone a general uplift in Pleistocene time.

II. SONORA DESERT

American geologists and physiographers have very aptly described the so-called Sonora Desert as a sub-province of the extensive Basin and Range Province of the western United States. The Gila Desert in Arizona and the Mohave Desert in southern California are northern extensions of the Desert of Sonora, in the extreme northwestern part of Mexico. A good idea may be had of this almost completely barren land by travelling by airplane from Los Angeles to Mazatlan or to Mexico City.

The characteristic aspect of this country is one of extensive flat lands interrupted by deeply eroded, short and low sierras with surrounding terraces and pediments. The mountains are not very high except in the eastern part where this sub-province joins the Western Sierra Madre of Mexico. All the waste lands are the result of a very advanced cycle of erosion of the mountains. There are a few bolsons, or inclosed basins, and several gently inclined plains sloping toward the Gulf of California. Rains are exceedingly rare and when it does rain, the waters are so quickly absorbed by the dry soil that they never reach the sea. This is true of all the streams north of the Sonora River.

Relatively large sandy wastes cover certain areas and contain the typically desert-type, crescent-shaped ridges or dunes formed by wind action. In other places, uniform, inclined plains between the low

ranges have temporarily a corrugated appearance due to water action. The valleys of the Altar and Hermosille rivers are about the only green lands found. Here, areas of vegetation and cultivated lands cut transversely into the enormous waste lands of the desert.

The low mountain ranges of this sub-province consist of volcanic and intrusive rocks as well as a few areas of sedimentary rocks.

As mentioned previously, the characteristic features of these desert lands are, to a certain extent, the same as those of the Basin and Range Province in western United States, but in a more advanced stage of erosion. The North-Central Plateau of Mexico shows, in parts, a striking similarity to the Great Basin in the western United States, while the Sonora Desert region merges into the North-Central Plateau of Mexico by a transition of forms in a relatively narrow belt along the international boundary. This region bordering Arizona and New Mexico is called by American geographers the Mexican Highland.

It is often supposed that the mountains of the Sonora Desert are really fault blocks, but the fault scarps have been so dissected by advanced erosion and covered by debris that it is now difficult to realize that these mountains ever had such an origin. Several residual mountains in the Sonora Desert having cores of volcanic or intrusive rocks were mantled with sedimentary rocks which have now been almost completely eroded.

N. M. Fenneman, in his book, *Physiography of Western United States*, summarizes in a few words the character of the Sonora Desert, when he says that

> the greatly eroded mountain forms, the striking development of rock plains, and the link of enclosed basins in a common drainage system, are the main features of this land.

III. COASTAL STRIP OF SINALOA AND NAYARIT

With more rain, more vegetation, more humidity, and numerous small streams and some large rivers, the coastal land bordering the Pacific Ocean is simply a southward continuation of the sandy, dry plain of the Sonora Desert. It extends for nearly 500 miles along the waters of the Pacific and between the foothills of the Western Sierra Madre Mountains and the ocean.

It would be very difficult to place a line of demarcation between this coastal plain and the Western Sierra Madre Mountains unless a contour level is chosen for that purpose. Individual sierras and isolated mountains are so common in some parts of the coastal plain that such areas might be included as part of the great cordillera moun-

tain province. Especially is this true in the southern portion which comprises parts of the states of Nayarit and Jalisco.

Before the present cycle of erosion and before the last uplift, the high mountains of the Western Sierra Madre probably reached the seashore. The now detached mountains or sierras of the coast, separated geologically in a few places by longitudinal valleys from the Sierra Madre, represent parts of that province, but show only the basement rocks with their mineral deposits exposed in some places. Most of the mineral deposits appear to be hidden below the younger eruptives in the Sierra Madre proper. There is no doubt about the very advanced erosion of these coastal mountains as some of them are obviously remnants of formerly much higher mountains. In northern Sinaloa several large pediments are seen where the disintegrated material has been spread out in the plains or carried away to the sea to form the continental shelf.

A history of its own completes the physiographic development of the coastal strip. Local volcanic flows have rejuvenated the much older degraded topography and introduced many changes. Small deltas have been converted into interior marshes or lagoons, cut by long sand bars, which parallel the coast through most of the province.

In the southern part of this coastal plain area, the hot climate, the thick fertile soil, and the frequent torrential rains during the months from June to September give rise to considerable agricultural wealth. Rice, tobacco, sugar cane, and many kinds of fruits are now grown in limited amounts and could be developed to sustain a much larger population. This large belt of coastal land offers opportunity for very extensive irrigation systems. Low hills scattered in these plains provide excellent places for new settlements where one could enjoy less heat and more breezes, but at the present, malaria and other tropical diseases are very common and sometimes there are epidemics.

There appear to be many important mineral districts in this province, which have not yet been fully developed. True fissure veins are commonly found, located in early Tertiary volcanic or intrusive rocks. A few metasomatic bodies are also found between limestones and dioritic rocks from which the sedimentary rocks have been removed by erosion. Silver-lead ores are the most common minerals found, but some narrow gold veins occur. Black, unoxidized ores also are found, indicating that oxidation and replacement zones have been washed out by erosion. In the state of Colima, comparatively large iron ore bodies are known to exist not far from the seashore. There is also a large series of oil shales in some of the mountains near the coast.

Near Banderas Bay, in the southern part of this coastal strip, the extensive *malpais* of basaltic rocks covers large areas. It is a well known fact that most of this coast, if not all of it, is subsiding at the present time. Some of the few good bays, such as Mazatlan, Topolobampo, and Guaymas, are really sunken valleys.

Fish, oysters, shrimps, *et cetera* are abundant along this coast and are only slightly exploited. Marine salt resources are great, especially in certain lagoons temporarily cut off from the sea by sand bars. Winds blowing from the south during winter months create stormy, heavy seas, sometimes rather dangerous for shipping. In the northern part of the state of Sinaloa, the old delta of the Fuerte River has built a large coastal plain, 30 miles wide. The rest of the coastal plain is much narrower and of irregular contour. In some of the barrancas, in the foothills of Sierra Madre, remnants of high terraces, indicating various uplifts, can be seen. The same terrace-like, short platforms are found facing the ocean in many places south of this coastal strip.

IV. WESTERN SIERRA MADRE

The Western Sierra Madre lies between the Central Plateau, the Sonora Desert and the narrow coastal plain of the Pacific. This cordilleran system of mountains is, in places, 200 miles wide and extends northwest and southeast for about 14° of latitude. This province has no direct physiographic continuation in the adjacent area of the United States, since the North-Central Plateau and the Sonora Desert merge to form what is called the Mexican Highlands at the northern end of the province. Near this end of Western Sierra Madre, where the Basin and Range Province changes gradually to Sierra Madre, the geology is rather complicated, due to the presence of numerous sedimentary ranges between others made of intrusive rocks. This province is characterized by eruptive rocks of Tertiary age overlying and burying older igneous bodies that contain great mineral wealth in the form of true fissure veins, fault veins, or contact bodies. The old diorites, diabases, or porphyritic andesites, generally greenish or brown in color, appear to have been originally formed as independent high ranges or isolated mountains, and in many places where they have been uncovered, they tower above the younger eruptives. These younger rocks consist of various types of andesites, or of thick horizontal or tilted sheets of rhyolites intercalated with breccias and tuffs, and still younger basaltic flows. Here and there, especially on the western slope, some of the rocks appear to be well folded Mesozoic sediments. These formations are either attached to the Sierra Madre or appear as isolated ranges scattered in the narrow coastal plain.

The average altitude of the Western Sierra Madre is about 7,000 feet, but there are summits that reach altitudes of 9,000 and even 10,000 feet above sea-level. The sierras are packed together with their parallel and uniformly high crests separated by deep canyons, with almost vertical walls tinted with brightly contrasting colors of great beauty. In other places the slopes are uniform but steep. Erosive action looks fresh and young and deep canyons near the top of the mesas are hanging ravines, locally called "quebradas." In a few places, the bottoms of the canyons are sufficiently wide to permit cultivation. Large tracts of the sierras are covered with forests, while in others, vegetation is rare, but mantled with brush, weeds, or grass, with trees only in the ravines. As a general rule, the canyons are so steep that streams are torrential in their upper courses.

The large rivers, which are numerous on the western side of this province, originate near the easternmost edge of the Sierra Madre which faces the Central Plateau. Most of the streams flow into the Pacific Ocean. Usually the upper and middle courses of these streams run more or less parallel with the general north-south trend of the sierras, but in their lower courses, they cut transversely through the mountains to empty into the sea. Near the ocean, ample valleys, taking the place of the narrow gorges, farther up, permit extensive cultivation in the coastal lands. These coastal lands are semi-arid in the northern part of the province where the Yaqui, Mayo, and Fuerte rivers cross it, but in the middle and southern parts the coastal lands are more fertile though very narrow in places. Near the south end of the province, physiographic conditions change sufficiently to warrant the creation of a sub-province, embracing the portion of salient coast near Bahia de Banderas and Cabo Corrientes. In this area which would include the lands west of the Guadalajara Valley, the Sierra Madre Province merges gradually into the Central Plateau of Mexico. Here, the mesa is broken and the edges of its tilted fragments are usually carved by deep canyons. In this section, there are several high volcanoes, some of which have eroded needles in the middle of their deeply eroded rocky craters.

We can not conceive the present physiographic aspects of this Sierra Madre without supposing that it has been formed by a tremendous and almost uniform uplift. Along the deep canyon through which the Lerma River flows after leaving the Central Plateau, there are fresh terraces about 300 feet above the bottom of the canyon. Except in the north and south ends, diastrophic movement was uniform enough to preserve the thick rhyolite sheets at the top of the sierras in their almost horizontal position.

In the Western Sierra Madre Province, the annual rainfall averages 25–30 inches. The climate is cold or temperate at the summits, mild on the slopes, and very hot at the bottoms of the canyons. Timber, cattle raising, and mining are the main occupations of this province. Agriculture, now practised on a very small scale, could be increased by the proper utilization of the waters of the streams in their lower courses within the canyons and along the narrow marginal coast.

There are many old eruptive ranges with their vein systems hidden under thick mantles of younger eruptives. Several worthy mining prospects, long ago discovered, remain idle due to difficulties in transportation, lack of proper technical advice, an abundance of underground water, scarcity of population, and isolation. We can safely say that in this province, the larger part of its mineral wealth is as yet relatively virgin. Geophysical means of investigation may some day help to develop some of the hidden mineral wealth of this region.

V. EASTERN SIERRA MADRE

Narrower and longer than the afore-mentioned Western Sierra Madre Province, is the so-called Sierra Madre Oriental (Eastern Sierra Madre) which extends from the Rio Grande border to the Isthmus of Tehuantepec, a total length of more than 1,000 miles facing the Gulf of Mexico. This long chain of mountains crosses the Rio Grande into the United States in the Big Bend region of West Texas. The high but relatively separated ranges found in Brewster and Presidio counties, Texas, mark the north end of this great physiographic feature extending from Mexico.

Southward through the state of Coahuila, the ranges of this great system come closer and closer together. So completely is the eastern edge of the North Central Plateau flanked by the ranges of this system that access to the interior is found only in a very few places. Except for very old trails that are unfit for use with modern vehicles, the upper part of the North-Central Plateau may be reached by automobile or railroad only through Monclova and Cuatro Cienegas. Saltillo, which is on the eastern edge of the North-Central Plateau, may be reached by automobile or railroad only through the tortuous passes that enter the Sierra Madre Oriental at Monterrey and Monclova. South of Monterrey the Sierra Madre Oriental presents an unbroken barrier to the interior that is pierced only by a very old trail from Victoria, Tamaulipas, to San Luis Potosi, the Tampico-San Luis Railroad and the new Pan American Highway to Mexico City. In each of these cases, man was called upon to use the best of

his engineering skill to make the difficult ascent to the Central Plateau.

The rocks of the eastern Sierra Madre Province are principally limestones, with some shales, and sandstones, mostly of Mesozoic age, but, as in the ranges of the North-Central Plateau, cores of older rocks are seen in many places. The Eastern Sierra Madre is composed of more or less individual parallel ranges closely packed together. The sedimentary rocks show complicated folding and faulting as results of complex movements. Thrust faults and *en échelon* faults are common, as are long anticlinal mountain ranges. In the eastern slopes, facing the Gulf coast, longitudinal fault scarps are seen in some places abruptly bordering the coastal plain. Between the sierras, deep synclines and graben fault blocks form large and small intermontane valleys; some of these form descending steps to the coast. Due to the highness of the Central Plateau, the elevation of Sierra Madre, when viewed from its western side, is not as imposing as it appears from the coast on the opposite side.

Where the Eastern Sierra Madre borders the South-Central Plateau of Mexico, the edge of this plateau ends abruptly against high volcanoes between which occur deep, steep "barrancas"—canyons and amphitheaters—which are cut into thick lava sheets. Tuffs cover the Mesozoic sedimentary rocks. Forests cover the slopes of these big volcanoes and most of the Eastern Sierra Madre on its eastern slopes. This is in marked contrast with the western slope which has a drier climate and much less vegetation as a rule. Erosion has carved "barrancas" in these mountains and enormous gulches and gorges several thousand feet deep, types of which may be seen when crossing this Sierra Madre from Tamazunchale to Jacala on the highway from Laredo to Mexico City. The Montezuma or Panuco River, with headwaters in the Valley of Mexico and its environs, flows for a long distance through one of these deep cuts. The crest of the Eastern Sierra Madre has an average height of about 7,000 feet. There are summits which reach 10,000 feet and several notably higher volcanic peaks that border the Central Plateau at the edge of the Eastern Sierra Madre. The Orizaba peak, capped with perpetual snow, is the highest mountain of Mexico and rises to 18,400 feet above sea-level. The "Cofre de Perote," also at the edge of the plateau, has an altitude of 13,500 feet.

The resistance of thick limestone beds to erosion in semi-arid climate gives the impression of an erosion cycle in its youth in most of the ranges composing the Eastern Sierra Madre. More advanced erosion is seen in mountains made of other sedimentary or volcanic rocks.

The rainy season in this province, like in the rest of the continental Mexico, extends from May to September. It rains more on the eastern slope than on the west and, due to the proximity of the Sierra Madre divide to the Central Plateau, only a few important streams flow toward the plains of the Central Plateau.

In the central part of this province, there are several areas of intrusive rocks which have been exposed by erosion near the summits of high mountains. These rocks have pierced Mesozoic limestones and in many places contain minerals at the contacts. This mineralization is composed mainly of copper ore containing gold and, in some places, lead-silver ores. Caves of lead deposits, as well as other types of mineral deposition in this region, have long been exploited.

Several mountain ranges detached from the Eastern Sierra Madre lie isolated in the coastal plain of northeastern Mexico and some mountains that reach the shores of the Gulf have been taken by geologists as the barrier which separates the Rio Grande Embayment from the Tampico Embayment. In the same manner, a long transversal spur range of the Sierra Madre reaches the waters of the Gulf to limit the Tampico Embayment on the south at its junction with the Isthmian Embayment. The Gulf Coastal Plain consequently is subdivided into three natural sections or sub-provinces, as described later.

VI. CENTRAL PLATEAU

A. NORTH-CENTRAL PLATEAU OF MEXICO

The North-Central Plateau of Mexico contains the so-called "high lands" and the great "Bolson," or basin areas. This province is really the southern extension of the Basin and Range Province of the southwestern United States, in Arizona and New Mexico. The North-Central Plateau with the Sonora Desert occupies about two-fifths of the area of Mexico. From Monterrey or Monclova to Saltillo by railroad or automobile, the ascent is made to the eastern edge of this highland area where the elevation is approximately a mile above sea-level.

The North-Central Plateau of Mexico is a desert and semi-desert. In the plain the average annual rainfall does not exceed 12 inches and in some places it is very much less than 10 inches. In the mountains it rains a little more. There are, in this area, wide daily variations of temperature, hot during the middle of the day and mild or cold early in the morning. In the most northern part, winters are cold and sometimes snow covers the tops of the higher mountains. Vegetation is scarce and consists of sage, mesquite, and many species of thorny plants and weeds. In some mountains, especially those of

eruptive and intrusive rocks, pines and other trees grow on the higher parts of ravines.

The North-Central Plateau, with more plains than mountains, extends as a large south-north inclined plane from its southern limit near the city of San Luis Potosi to the Rio Grande and east of Ojinaga. Though in San Luis Potosi, the altitude of the plain is 6,130 feet above sea-level, in Torreon and Ciudad Lerdo in the "Bolson de Mapimi," it is only 2,560 feet. Northeast of Ojinaga, and west of the Rio Grande, the highlands and bolsons again rise to higher altitudes above sea-level; the elevation of El Paso and Ciudad Juarez is 3,800 feet.

With the exception of the Rio Grande drainage basin, the North-Central Plateau of Mexico has no outlet to the sea. This plateau consists mostly of large plains, which really are inclosed basins between long, narrow, isolated sierras. Many of these sierras are more than 65 miles in length, while their width rarely exceeds 10–12 miles. The sierras, in general, extend northwest and southeast, but in a few sections, west of Monterrey and in central Coahuila, they extend predominantly east and west. Almost all the sierras of the North-Central Plateau consist of sedimentary rocks with a remarkable abundance of Cretaceous limestone. Triassic, Jurassic, and, in places, Paleozoic sedimentary rocks occupy the cores of the axes of the sierras where the more advanced erosion or faulting has left the older rocks uncovered. Post-Cretaceous intrusives also appear in several mountains, and have lifted the sedimentary rocks into a quaquaversal position. Eruptive rocks, like andesites, are also common, as well as some basalts, but these are usually found in the synclinal valleys.

The sierras generally have crests of even and uniform altitudes and their flanks are usually steep with deeply carved V-shaped ravines. The lower part of the slopes are commonly covered with extensive fans that form a continuous belt of alluvial material solidly cemented with caliche along the flanks of the mountain. In some places, especially in narrow basins or bolsons, or on mountains built with eruptive or intrusive rocks, the fans are small and independent, causing a sharper contrast between the mountains and the plain. In some of these basins, the bases of the sierras extend toward the middle of the plain like very gently inclined planes which end at the "barrial," improperly called "playa" by the American geologists and geographers. The topographic elements of the basin or "bolson" are the mountain slope, the alluvial fans, the gentle alluvial plain, and the silty bottom of the basin called the "barrial" which is temporarily occupied by water immediately after the infrequent but torrential rains. Isolated ranges are explained as fault blocks in sedimentary rocks pre-

viously folded in large anticlines and synclines. In many places, more complicated folds are seen, such as fan folds and asymmetric anticlines, but the big intervening synclines are usually occupied by basins. Thick masses of conglomerates intercalated with clays fill the bottoms of many of the basins and, in some places, loess deposits are found.

At the center of the North-Central Plateau, large rivers—for example, the Nazas and Aguanaval—have their headwaters in the Western Sierra Madre Mountains and bring down annual floods and torrential waters. The water is now utilized by means of dams and canals for irrigation; thus, the ancient lake beds near Torreon at the bottom of the big "Bolson de Mapimi" have been transformed into very fertile lands with large cotton plantations.

In general, the actual forms of the ranges of this province do not show a very advanced cycle of erosion. Only in certain types of rocks has erosion reached any degree of maturity. In some areas, fault blocks in rocks not previously folded have produced extensive mesas, monadnocks, and buttes, some with lava sheets on top.

B. SOUTH-CENTRAL PLATEAU[3]

On account of the mildness of its climate, the abundant rainfall, the fertility of the soil, its beautiful scenery, and its geographic location, this province is the most populous of Mexico and has been the theater of the most important events of all the history of Mexico. The city of Mexico ranks among the large cities of the world, having more than 1,250,000 inhabitants.

Geographically considered, the Central Plateau of Mexico is the southern continuation of the North-Central Plateau, but the special characteristics of this sub-province are its high altitude above sea-level and the large number and extent of its picturesque and fertile valleys separated one from another by relatively short mountain barriers.

The former curvature of the Western Sierra Madre of Mexico toward the southeast seems to indicate that the present architecture of this central province is built over a mountainous area which was formerly a part of the Western Sierra Madre. The growth in altitude of the Central Plateau is due, in part, to enormous amounts of volcanic materials poured out through long fissures, and finally through a num-

[3] As a sub-province of the Central Plateau Province, the words, "South-Central Plateau," seem entirely appropriate, but following the common usage in Mexico, even among geographers, the name, "Central Plateau of Mexico" (Mesa Central de Mexico), is convenient in designating this southern part of the Central Plateau Province (Mesa Central Mexicana).

ber of chimneys on which very high cones were built. It is to be noted that most of the higher volcanoes lie along an east-west line, from the Gulf to the Pacific, forming the southern limit of this Central Plateau. It is thought that this series of latent or recently extinct volcanoes, represents the end of the important volcanic history of this region.

Rhyolites, dacites, varieties of andesites, trachytes, and basaltic andesites make up the mountain masses, but the valleys, which were originally deep lake basins, have been filled with alluvial and lacustrine material derived from the mountains and with enormous cinder masses from the younger volcanoes. When the strong volcanic action ended, the lakes were already converted into shallow-water sheets, which gradually dried up, and later became lands suitable for cultivation. In Pleistocene time, before the lakes were extinct, abundant fauna, especially mammalian, existed here. The complete drying-up of these valleys was probably due to a less humid climate and to the drainage of these basins, when water carved outlets to the ocean and connected the various basins. Approximately at Latitude 23° N., two long rivers drain extensive areas of the Central Plateau: one river, the Lerma or Santiago, flows toward the Pacific and the other, the Moctezuma or Panuco River, toward the Gulf of Mexico, emptying at Tampico. Numerous relatively small lakes are still found in some of the western parts of this province. Some of these lakes are enlargements in the course of rivers; for example, Chapala; others are formed by the retention of waters by recent volcanic barriers, like some lakes in the state of Michoacan. Few lakes—for instance, the now almost dry Texcoco Lake, in the Valley of Mexico—represent the type of the former basin lakes.

Here and there, projecting from beneath enormous piles of young volcanic material, older sedimentary or intrusive rocks are found and most of the mineral wealth of this province is found in these older rocks. Mining districts—for example, Pachuca and Real del Monte Huautla—have their veins in linking fissures, or along faults in green or pinkish porphyritic andesites of the type of those of the Western Sierra Madre. A row of silver-lead mining centers, almost at the middle of the Central Plateau, as at Zacatecas, Guanajuato, San Felipe, El Oro, Zacualpan, Taxco, and Temascaltepec, have their veins in sedimentary series of Triassic-Jurassic age. A few districts contain lead ores in irregular pockets in Cretaceous limestones, whereas most of the bodies of copper gold ores lie at the contact of metamorphosed limestones and diorites, monzonites, or porphyries. The parallel volcanic ranges between the basins seem to be located along faults in the basement rocks and, in some places, smaller transverse ranges indicate

a network of fault fissures. The high volcanoes, which built the south barrier of the Central Plateau, are probably located along a transverse fault, south of which the general mountain structure is different.

On the flanks of some of the ranges, where the highest summits rise, occur extensive, thick, inclined beds of tuffs, gravels, and boulders, which were probably transported by the torrential rains, following the last glacial period. The tops of these high mountains were once covered by extensive glaciers and although recent erosive action has reduced the original altitude of many of these ranges, the present form of the mountains in the plateau shows, generally, an almost juvenile topography or an erosive work which is far from reaching maturity. A few volcanic cones, like Popocatepetl, Citlaltepec, and Ixtaccihuatl, on account of their altitude, more than 12,000 feet, are crowned with perpetual snow, below which cirques and slopes covered with tillites are evidences of a glaciation far below the present snows.

By studying the shape of the tops of the higher volcanoes and the petrographical sequence of the rocks found on them, the relative age of these cones can be ascertained. Ixtaccihuatl, for instance, an old volcano (elevation, 16,900 feet), has an elongate crest which was formed by a succession of thin lava sheets and breccias that were erupted by craters which have now entirely disappeared. Some cones older than Ixtaccihuatl show only the cores of the rock material which filled the craters, whereas some other high volcanoes still show their solid calderas in their summits, only partially dissected by the erosive action of trade winds and rains. A good example of this is Ajusco, an old extinct volcano, which rises majestically south of Mexico City.

Popocatepetl (elevation, 17,830 feet) is a rather young volcano. It is almost perfectly conical in shape and has high scarped walls forming the crater. This volcano, second peak in height in Mexico, is not entirely extinct; the inhabitants of this city in the past centuries frequently saw dense clouds of vapors and ashes coming out of the crater. In the walls of the crater, the alternation of hard lava and breccias demonstrate the structure of an almost perfect type of volcanic cone with its characteristic, decreasing extent and thickness of the lava flows toward the summit. The same structure is seen in Orizaba, the highest peak of Mexico (elevation, more than 18,000 feet), and in the Colima volcano, the westernmost peak of the east-west row previously mentioned as bounding the Central Plateau on the south. Colima is even more active than Popocatepetl, its paroxysmal eruptions being more violent and frequent.

The long volcanic history of the Central Plateau of Mexico ended with extensive flows of basaltic lavas, ejected through narrow chim-

neys, crowned afterward with small cinder craters either in the middle of the valleys or in the flanks of the ranges. Successive basaltic lava flows, in steps, on the slopes of the mountains, are seen south of the Valley of Mexico. East of Ajusco, on its flanks or on the top of the basaltic mesa surrounding this mountain, more than 100 craters can be counted. The large water supply of Mexico City comes from springs near Xochimilco. These waters follow a long subterranean course through old ravines and barrancas of Ajusco, which were covered by thick basalt lava sheets, thus securing a water supply of great purity. Some of the basaltic lavas are so young that human remains are found under them. A very extensive basaltic flow in 1759 covered a sugar cane plantation on the Jorullo farm in the state of Michoacan. In the state of Nayarit, in 1870, Ceboruco ejected through a new crater a thick lava flow that covered a large area. There is no doubt that the first men who appeared in this country watched numerous volcanic eruptions because they left the impression of their feet on the volcanic muds and in the ash beds of some volcanoes. Human footprints are found at Amanalco in the state of Mexico, buried under 300 feet of younger tuffs and gravel beds.

VII. BALSAS BASIN

Beyond the southern barrier of the Central Plateau of Mexico and separated from the Gulf by the high Eastern Sierra Madre and from the Pacific by the Southern Sierra Madre, lies a very mountainous country drained mainly by the Balsas River which originates on the southern volcanic flanks of the previously mentioned Central Plateau. In general, the sierras composing this province, though branching in several directions, have a general trend east and west, almost paralleling the Southern Sierra Madre. The course of the Balsas River follows this trend until it turns southwest toward the Pacific. Most of the larger tributaries of this river come from the north and join the main stream from the right bank; however, there are very many short streams which enter from the left bank. This condition is due to the fact that the summits of the Southern Sierra Madre which limit this province on the south, are very close to the seashore. Between the mountain ranges of the Balsas Basin, there are scattered large and small valleys. These valleys are linked by narrow and steep canyons through which flow the tributaries of the Balsas River. This is also true along the course of the main stream itself which flows through long valleys and narrow canyons.

The climate of this mountainous province is very peculiar. The rainy season is relatively short; the rains occur generally at night and

are torrential but of short duration. Because of the lack of regular winds, the valleys, ravines, and canyons are extremely hot. The diurnal variations of temperature are very small; for this reason, the inhabitants of the region call it the "Tierra Caliente."

The vegetation is scarce, except in certain sierras, due to the steepness and rocky nature of the mountains. It might also be noted that this peculiar vegetation is neither tropical nor temperate, but has characteristics all its own.

In this region, the Mesozoic sedimentary rocks are predominant and they are intensely folded and faulted. Eruptive rocks, such as andesites of various types, and basalts are scattered throughout the sedimentary areas, in some places forming long ranges. Intrusives are also found in several places and this area, in general, is so broken by faults and in such a state of suspended adjustment, that earthquakes are rather frequent. This province as well as the adjoining province of the Southern Sierra Madre, constitutes the main seismic center of Mexico.

We do not have as yet sufficient data to describe the successive geological events that have taken place in this country. We only know that successive uplifts have occurred since Mesozoic time and that, subsequently to these uplifts, the province contained many large lake basins without outlets, in which were deposited thick beds of conglomerates and sandstones.

Packed folds and synclines in Mesozoic rocks cut by faults and erosion are responsible for the forming of canyons; also these early and middle Tertiary formations were later eroded to form the deep canyons and ravines which now connect the afore-mentioned basins; thus the drainage of these basins was accomplished through the Balsas River and its tributaries.

In this province, contact mineral deposits are found lying between limestones and intrusives. Copper deposits capped with large iron gossans are encountered in some places; copper ores are also found in veins in the earlier red conglomerates which filled the basin. Narrow quartz veins containing gold are found in the diabases, monzonites, and granites. There are small masses of iron ores near coal seams in highly folded rocks of Triassic age, especially in the Mixteca region. Small deposits of other minerals such as quicksilver, antimony, silver, and lead are also found.

VIII. SOUTHERN SIERRA MADRE

Along the Pacific Coast southeast of the end of the Western Sierra Madre and south of the Balsas Basin, the Southern Sierra Madre ex-

tends to the Isthmus of Tehuantepec. These mountains and their foothills are so close to the ocean that there is practically no coastal plain except in isolated areas. In some places, the ranges rise abruptly from the sea. The crests of the ranges are uniform except in places where isolated mountains rise above the general average. The dividing crest reaches an average altitude of about 7,000 feet, but there are some mountains which reach a height of 8,000 feet.

Extensive forests cover the southern flanks of these ranges, but on the opposite side toward the Balsas River Basin, the vegetation becomes scant, consisting mostly of oaks on the higher levels while on the lower flanks grow cactus and other plants typical of the Balsas region.

It rains considerably from May to October in these mountains and the climate, which is hot in the barrancas, is refreshed by marine breezes on the slopes facing the ocean. South winds of cyclonic character occasionally sweep the coastal flanks during the winter months.

Paleozoic sedimentary rocks, and granites and pre-Cambrian crystalline schists covered in places by Mesozoic limestone form the mountain ranges of this province. The overlying Mesozoic sedimentary beds evidence a very advanced stage of erosion.

In the northwestern part of the province, high cliffs facing the ocean indicate relatively recent faulting and uplift. The Southern Sierra Madre Ranges face one of the abyssal depths of the Pacific Ocean. The whole region is broken by faults, the adjustment of which causes frequent earthquakes. However, several of the disturbances in this area have come directly from the ocean. Submarine earthquakes have been the cause of the port of Acapulco being destroyed by ocean waves rushing into the bay, three or four times the last four centuries. Bays such as Zihuatenejo and Acapulco are sunken valleys.

In the Mesozoic rocks are found silver-lead ores in veins and pockets and in the gneissoid rocks interbedded quartzites bearing gold are found in some places. The disintegration of old granites has caused the formation of gold placer deposits along the coast. Practically all the streams in their lower courses have small amounts of gold. In the northwestern part of this province, in the state of Michoacan, contact iron ore masses crop out between limestones and diorites. Near the mouth of the Balsas River, there exists one of the largest masses of iron ore known in Mexico. It has been calculated that 15 million tons of iron ore are exposed at the surface.

IX. SIERRA MADRE OF CHIAPAS

Beyond the Isthmus of Tehuantepec, three large provinces of Mexico lie within Central America: a large part of the southeastern

coast of the Gulf of Mexico; the Yucatan Peninsula; and the Chiapas Province, which comprises the mountainous area east of the Isthmus with the southern narrow coastal plain at its foot on the Pacific. Although geologists and travellers subdivide the mountainous area of Chiapas into several sections, differing in their topographic and geologic aspects, nevertheless, their related and combined features can be taken as a whole to form one large province. While the Chiapas Province appears to be the eastern extension of the Southern Sierra Madre of Mexico, the Isthmus between is topographically different from both and because of the lack of topographical continuity as well as several geological reasons which become more and more accentuated east of the low Isthmian passage, the Sierra Madre de Chiapas is regarded as a separate province. The geologic and physiographic history of Chiapas corresponds with that of Guatemala in Central America more than with that of the Southern and Eastern Sierra Madre of Mexico in North America.

The Chiapas Province consists of three divisions. The first is a group of coastal mountain ranges with steep slopes on the south, toward the Pacific, and gentle slopes on the north. This range is formed mainly of Archeozoic and Paleozoic granites and crystalline schists. The second division is a long structural depression paralleling the coast range on the north side. Along this depression flow rivers that originate in Guatemala and combine to form the great Grijalva River which flows through the coastal plain of Tabasco to empty into the Gulf of Mexico. This depression or great valley of Chiapas, as it is sometimes called, is bounded on the north by the steep and commonly scarped slopes of the high central plateau which is called the "Mesa Central de Chiapas." This central mesa, like the other divisions, has a west-northwest and east-southeast elongation. While the big valley has an elevation of 1,200–2,500 feet above sea-level, the "Mesa Central" has an average elevation of about 7,000 feet.

Both the valley and the "Mesa Central" are formed principally of Middle Cretaceous limestones which are either slightly folded or in nearly horizontal position. The high plateau or mesa is composed chiefly of Pliocene sandstones and shales. Here also are found Pleistocene beds which are usually of detrital material or tuffs eroded from the high mountains farther north. These last-mentioned mountains are formed of young volcanic rock and, in this range, Zontehuitz, with an altitude of 8,700 feet, is probably the highest mountain in Chiapas.

Near the Guatemalan border and between the granite range of the coast and the Cretaceous rocks of the big valley, there enters a wedge

of Devonian (?) shales known as the Santa Rosa formation and some Carboniferous limestones. The latter cover large areas and form extensive mountain ranges in Guatemala.

Between the alluvial plains of Tabasco and the "Mesa Central" of Chiapas there is a broad belt of slightly folded Tertiary rocks. This area is rugged hilly country, high above sea-level, and completes the mountainous province. It is covered with a dense, tropical vegetation which contrasts strongly with the dry, almost barren land of the "Mesa Central" and with the relatively scarce vegetation of the Pacific coastal mountain range.

The Tehuantepec Railroad crosses the Isthmus north and south. The highest point along the railroad is only a little over 800 feet above sea-level. On both sides of this passage, mountains 2,000 feet high are seen. These belong to the Southern Sierra Madre range on the west and to the Chiapas Range on the east. This passage is located in the saddle between the east end of the Sierra Madre Range and the west end of the Chiapas Range. The advanced erosion of the granite rocks on the Pacific side has facilitated the approach to the west coast.

The three peculiar characteristics of the mountainous area of Chiapas, as pointed out by Böse, Sapper, and other travellers, are: first, the existence of the large belt of Tertiary marine sedimentary rocks not found in any other section in Mexico, except along the coastal plains of the Gulf of Mexico and at much lower levels; second, the large areas of Cretaceous rocks tilted up as a mass without intense folding, but cut by longitudinal faults *en échelon* toward the north; and third, the extensive granitic Pacific Sierras that have emerged since the Paleozoic time.

On an extensive zone of the mountainous area of Chiapas that faces the Tabasco coastal plains, the rainfall is very heavy, averaging 80 inches annually. It is one of the most typically tropical areas in Mexico.

The eastern part of the Chiapas Province is the western continuation of the mountainous area of Guatemala and of part of the vast territory of the Departmento del Peten and Alta Verapaz of that Republic, with a similar physiographic history. The karst topography is very characteristic of the extensive limestone areas of the central plateau of Chiapas.

X. PENINSULA OF YUCATAN

The Peninsula of Yucatan shows physiographic characteristics entirely different from the rest of Mexico.

The three-fourths of the Yucatan Peninsula, which belongs to

Mexico, is an extensive, almost flat area, appearing like an enormous slab—"the slab of Yucatan," as it is commonly called by geographers and geologists. It rises very little above the level of the sea and its prolongation extends far out below the waters of the Gulf, especially on its northern and western sides.

It is essentially a limestone country of late Tertiary age, bordered on the north and the west by a belt of Pleistocene rocks, all beds lying almost horizontally or sloping gently toward the north, so that the highest points lie along the boundary of the state of Campeche, opposite the Department of Peten in the Republic of Guatemala.

The surface of this flat land is not uniform, due to many slight rugosities and undulations formed by erosive action. In this extensive land, there are no rivers or permanent streams of any kind in spite of its heavy annual rainfall; all rain water goes underground through holes and sinks and ordinary percolation through subterranean channels to accumulate in extensive flat caves or in sand beds at varying depths below the surface. These extensive underground reservoirs, the only permanent sources of water for domestic and other uses in the peninsula, are called "cenotes" and vary in depth from a few feet to 100 or more feet below the surface. Many of these subterranean pools have been known for centuries and are easily reached by trails or paths in the jungle. The sun penetrates occasionally to these underground water sheds through holes or openings; others remain in the dark with high or low rocky stalactitic roofs. The city of Merida is noted for its numerous windmills used to raise water from shallow depths. The annual rainfall of most of the Yucatan Peninsula averages about 40 inches, but farther south and west it rains considerably more.

Tropical vegetation covers most of this land except on the north and west edges, near the sea. In the interior, large areas have been cleared for cultivation and pastures. There are large plantations of sisal or henequen. In the middle and southern parts of the peninsula, the tropical vegetation is heavier, forming almost virgin forests. Only a few narrow trails have been cut by men who extract chicle, the only industry developed in these lands. Over extensive areas of the peninsula, the prevailing soil is a characteristic, red residual clay left from limestone dissolution.

Near the southern boundary and also in the center of the state of Campeche, a few narrow ranges of hills and ridges rise to more than 250 feet above the general level of the plain. These hills are composed of limestones that are different from those lying horizontally in the surrounding area. A similar long, low, narrow ridge extends northwest

and southeast between Halacho and Ticul and between Ticul and Peto near the southwest boundary of the state of Yucatan. This range of hills is known as the Sierrita and is about 75 miles long. It is the outstanding topographic feature of these states. In the northern part of Peten, a longer and higher ridge, which is a wide anticline of Cretaceous limestones, extends almost east and west, from near the town of Libertad in Peten (Guatemala) to Tenosique in Tabasco (Mexico).

In the eastern and southern parts of the peninsula are numerous lakes called "aguadas," some of them long and narrow or of a crescent shape. These are probably formed along faults or by sunken blocks along caves. Small scarps along the northern shore of Itza Lake in Peten appear like fault scarps. The bottom of the lake is an inclined plane with the deepest water occurring along the foot of the scarps.

Examination of the Pleistocene beds near the city of Merida and in other parts of the peninsula shows regular alternations of yellowish, compact, fossiliferous limestone and very porous, sandy, chalky beds. The local name for this soft rock is "sahcab." Its sedimentation was localized in very shallow, oozy water, as distinguished from the compact limestone made in deeper seas. In Pleistocene time as well as in late Pliocene, the peninsula suffered various movements of submergence and emergence, receiving deposits which evidence both shallow and deeper water sedimentation. Some underground water sheets remain in hollow spaces after "sahcab" beds have been removed by subterranean streams. It is supposed that the Tertiary beds of the peninsula overlie Cretaceous rocks at considerable depth.

The eastern shores of the peninsula, facing the Caribbean Sea, in Quintana Roo territory and British Honduras, extend a length of more than 5° of latitude in contrast with the western shore line in the Gulf of Mexico which extend only 3°. The south end of this line is a part of the shore line of the large lagoon of Terminus in the state of Campeche.

XI. GULF COASTAL PLAIN

The Gulf Coastal Plain, which extends from the Rio Grande to the Peninsula of Yucatan, has been divided into three large sub-provinces because of the characteristic physiographic differences which exist in these areas.

A. RIO GRANDE EMBAYMENT

The Rio Grande Embayment Sub-Province embraces a wide area on the right side of the Rio Grande, extending to its mouth, and a wide belt bordering the Gulf of Mexico as far south as Latitude 23° N.

The Laguna Madre extends along the Gulf coast southward from the Rio Grande to near the southern limits of this sub-province. This lagoon is separated from the Gulf by long, narrow sand bars. Low sandy land and swamps are found on the inland side, bordering the lagoon as is the case north of the Rio Grande in Texas.

The climate is dry and semi-arid. The vegetation is poor and consists mostly of low brush. Rainfall over this area is less than along the Coastal Plain of Texas.

Tatum has divided the area here described into three zones: (1) the eastern part with uniform plains dipping gently toward the sea and bounded on the west by the Reynosa escarpment, a north-south line of hills covered by gravel beds which are known as the Reynosa gravels; (2) the central zone which consists of low rolling hills and broad, shale-covered flats bordered on the west by a series of high, strike ridges including what is called the Ceja Madre and farther west a broad shale-covered area, broken by low gravel and caliche-covered mesas, extending westward to the front ranges; and (3) the front ranges of the Sierra Madre Oriental, which are included in the Eastern Sierra Madre Province, in this paper.

Within the southern part of this sub-province there are isolated mountain ranges which have much geologic significance. Of principal note are the Sierra de San Carlos and the long, more or less evenly elevated range known as the Sierra de Tamaulipas with the long, wide mesa known as the Mesa de Solis which connects the two ranges. These two ranges appear to be genetically related. They are formed principally of Lower Cretaceous or Comanche limestones. The Tamaulipas Range is a long anticlinal arch while the San Carlos Mountains have a more quaquaversal form and complicated structure with a large intrusive mass of diorite. The Mesa de Solis is a long, low anticlinal arch formed by Cretaceous limestones and shales covered, in part, by recent gravels and caliche. Staub thinks these ranges represent an important "plis de fond," that is, a large fold raised in a geosyncline. Some geologists do not agree with this theory, but think that these ranges may be older than the present Eastern Sierra Madre. Their tectonic interpretation is a problem which apparently has not yet been solved.

Farther east and roughly paralleling the Tamaulipas Range lie the Sierra de los Maratines and the Sierra de San Jose de las Rusias. These low ranges are formed by Middle Tertiary beds with a few dikes and sills of basalt. In the Soto La Marina valley are found hills —for example, Cerros del Aire, Tampiquito, and La Palma—which are formed by fossil coral reefs.

In the northern part of this sub-province two or more peneplain levels can be distinguished. Geologically, the formations north of the San Carlos Mountains are similar, in most respects, to the formations of adjacent Texas. The Eocene section is very thick and has many domes and anticlines which have been mapped in detail by geologists of the oil companies. The areal extent of the Eocene beds narrows remarkably toward the south and there is a marked lithologic change in them. The Oligocene and Miocene beds which have narrow outcrops in the north widen notably toward the south. The Oligocene and Miocene formations of the southern part of this sub-province are more easily correlated with formations of similar age of the Tampico Embayment than with those of the Texas section.

B. TAMPICO EMBAYMENT

The Tampico Embayment comprises the Coastal Plain region between the Eastern Sierra Madre and the Gulf of Mexico and from Latitude 23° N. south to Latitude 19° 40′ N. As indicated in the discussion of the Rio Grande Embayment, the northern extremity of this sub-province is marked by a spur of the Tamaulipas Mountains, which extends eastward to the Gulf in the vicinity of Punta Tordo. Its southern limit is northeast of the city of Jalapa and is formed by a volcanic spur of the Eastern Sierra Madre which extends to the sea at this place. The average width of this area varies from 50 to 90 miles.

As the climate here is warmer and much more humid than in the Rio Grande area, the vegetation is much more abundant and is of a tropical nature. From July to November and occasionally in the winter months, the rainfall is very heavy. The great fertility of the soil makes it possible for farmers to grow as many as three crops each year. This region produces in abundance nearly all tropical and subtropical fruits, corn, tobacco, rice, vegetables, vanilla, rubber, chicle, and some varieties of the finest hardwoods. It would be difficult to overestimate the production possibilities of this area if it were properly cultivated and attended.

This area is subject to the same unhealthful conditions that characterize all tropical areas, but in recent years medical knowledge has greatly helped in the improvement of public-health conditions.

Physiographically, we find the Eastern Sierra Madre Province in the west standing out with great relief. The area farther east is one of hills and comparatively low, rolling country followed by a zone of higher hills, mesas, and low mountain ranges. Shale valleys border the last-mentioned zone on the east. Next are a series of low sandstone

and limestone hills followed by a plain sloping gently to the sea. The Tamiahua Lagoon occupies a long stretch of the coast from just south of Tampico to the Tuxpam River.

This area has a number of large rivers, some of them navigable in part. The most important are: Panuco, Tamesi, Tuxpam, Cazones, Tecolutla, and Nautla.

The geologic conditions are almost entirely the cause of the physiographic and topographic features found in this sub-province. The mountain front is formed by folded, faulted, and upthrust masses of Comanche and Cretaceous limestones. The lower area farther east is formed of Cretaceous shales and interbedded sandstones and shales of Eocene age. The zone of mesas and low mountain ranges is largely of structural origin. Most of these topographic features are interrupted by igneous rock, commonly basalt, which came from intrusions and eroded flows. The valleys on the east are commonly formed by Oligocene shale formations. The hill area bordering this zone is formed by interbedded sandstones and shales of Miocene age. The plain sloping gently toward the east is formed by loosely consolidated Pliocene and Quaternary beds.

One of the striking geologic features of the Tampico Embayment is the number of volcanic plugs and other igneous hills which occur throughout the area. These isolated hills usually rise from 100 to 500 feet above the level of the surrounding plains. A few of the significant plugs or volcanic hills are: Aldama, Bernal de Horcasitas, those between Panuco and Ozuluama, Sabana Grande, Tlacolula, Sabanilla, Tres Hermanos, Tepezintla, Ixtle, Sierra de Tantima, and Las Tetillas. The oil fields of Juan Casiano, Cerro Azul, Cerros Viejo, and Chapopote are noted for their proximity to volcanic plugs.

The economic geology of this area is featured by its tremendous oil deposits. It has produced to date approximately 1,700 million barrels of oil. The number of oil seepages found in this sub-province is truly remarkable. The most common form of seepage is nearly circular with a diameter of 5–50 feet or more, covered with heavy asphaltic oil surrounding the small hole through which fresh oil slowly runs and gas bubbles up continuously or periodically. The big, broad, buried anticline north of the Panuco River is the south-plunging end of the Tamaulipas Mountains. On this structure are found the Chapacao, Cacalilao, Ebano, and Panuco oil fields. About 65 miles south of Tampico and bordering the Tamiahua Lagoon is the north end of the other famous buried structure known as the Golden Lane, which is marked by an almost continuous row of oil fields. This structure is narrow and is commonly considered to be faulted on both sides.

In the southern part of the Tampico Embayment, in the Papantla district, a new oil field has recently been discovered. Here the structure appears to be a broad, flat-topped dome. Production is encountered at an average depth of 7,600 feet. If this field is not a continuation of the Golden Lane structure, at least it is the result of similar geologic phenomena in connection with the Eastern Sierra Madre uplift. Because of general geological conditions, it is expected that additional buried folds in Cretaceous rock will be discovered in this sub-province as well as in the northern part of the Isthmian sub-province farther south.

This coastal sub-province is of special interest to the archeologist. It abounds in human relics from the most primitive to recent Indian civilizations. It is thought that ancestors of the Mayas, who achieved such great development in Yucatan and Central America, lived in a more primitive stage in the vicinity of the Panuco and Tamesi rivers. Remains of their archaic culture have been found in the jungles between these rivers. South of the Panuco River superposition of cultures is characteristic; ruins of civilized peoples, elaborate pyramidal structures, and mounds and images of varied sorts and descriptions give mute evidence that different tribes inhabited these beautiful coastal lands for long periods of time.

C. ISTHMUS OF TEHUANTEPEC

The Isthmus of Tehuantepec is the southernmost and broadest of the sub-provinces of the Gulf Coast. It comprises three-fourths of the total width of the Isthmus of Tehuantepec.

Some geologists think that the exceptional width of this Coastal Plain may be due to the action of the trade winds blowing normally and continuously, thereby facilitating the formation of bars and natural dams. The basins behind these bars and dams were later filled by sediments brought in by the rivers. For this reason most of the land is flat and swampy. Where the largest river, the Grijalva, empties into the Gulf a large delta plain has formed.

This broad coast is the most tropical part of all Mexico and has the most humid climate. In the southern part, rainfall sometimes exceeds 200 inches per year. Vegetation is so dense that there are places where the sun's rays never reach the ground. Fine cabinet woods are abundant, especially in the hilly country adjoining Chiapas and in the flat area adjoining Yucatan.

In the northern part of this sub-province and in the southern part of the state of Veracruz, there is an extensive swampy area which marks the divergent course of the Papaloapan River. This river has

headwaters in the easternmost part of the Balsas Basin Province and crosses the the Eastern Sierra Madre through deep canyons to reach the intermontane valleys of the Gulf side. It crosses the Coastal Plain and empties into the Gulf at Alvarado harbor. This Papaloapan Valley is extremely fertile and has extensive plantations of bananas, tobacco, rice, *et cetera*. Coffee and hardwoods grow profusely on the slopes of the foothills of the Eastern Sierra Madre. Other rivers of great importance in this area are the Usumacinta, which drains a very extensive territory in the states of Chiapas and Tabasco; the Grijalva, the most noted of all this sub-province because of the extent of its ramifications, multiple swamps, and lagoons; the Coatzocoalcos; and the Tonala. All these rivers provide almost the only transportation to the interior lands where roads are poor or entirely lacking.

The low country of the Isthmus is interrupted northwest of Puerto Mexico by high mountains called the Sierra de Los Tuxtlas. This sierra is made of volcanic rocks and has a few craters, like the volcano of San Martin, which was in eruption in the eighteenth century, throwing out clouds of ashes which covered extensive tracts and formed thin beds even in the Papaloapan swamps. The Sierra de Los Tuxtlas group of volcanoes forms the eastern end of the afore-mentioned east-west row of volcanoes across Mexico, crossing the southern edge of the Central Plateau and ending farther west with the famous Colima volcano near the Pacific.

The foothills in the eastern edge of the Chiapas Province are formed of Cretaceous and early Tertiary sedimentary rocks. The hilly country of Pichucalco exemplifies the rugged character of the country south of the Coastal Plain. Cretaceous and Eocene formations are found along the southern and western edges of this sub-province, whereas toward the Gulf, continuous areas of Miocene beds may be seen. Most of this area, however, is covered by a thick section of Pliocene and Pleistocene sediments, as well as a thick mantle of Recent soil.

In the foothills of the southern and western parts of this province, folds and faults are common. In most of the area, the Pliocene beds are practically horizontal except where disturbed by upward growth of salt plugs or by local faults. Surface geological studies are very difficult in this area due to the softness of the formations, the thick mantle of soil, and the dense tropical vegetation.

Some years ago an English company exploited an interesting contact deposit of gold and copper, that was found between a mass of monzonitic rock and Mesozoic limestones in the area just west of Pichucalco at the edge of the sub-province. After one large ore body

was worked out, the business was abandoned, probably due to natural difficulties and to scarcity of ore above the water level.

One of the most important economic resources of this area is now oil. Exploration work has been carried on here for many years and the oil that has been found is usually of higher grade than the oil of the Tampico Embayment. The discovery of some good salt domes gave this area real importance as an oil producer. Since then other salt domes have been found and prospects are favorable for the discovery of more domes in this area. A fairly large refinery has been installed at Minititlan and at the present time the Isthmus produces about 30 per cent of all the oil produced in Mexico.

XII. VALLEY OF OAXACA

The Valley of Oaxaca lies at Latitude 17° N. and is approximately 100 kilometers long, with an average width of 10–20 kilometers. It has an average elevation of about 5,000 feet with a slight inclination toward the south. This valley has a special interest as it is formed at what is considered the junction of the great eastern and western mountain systems of Mexico.

Due to its latitude, location and elevation, the climate is mild and even. Rainfall is heavy from June to September, but there are only occasional showers during the rest of the year. Agriculture and mining are the principal occupations of the inhabitants of this fertile valley. The Oaxaca Valley is drained by creeks which are tributaries to the Atoyac River, a tributary of the Verde River, which empties into the Pacific. Here are found the seats of the ancient Mixtecan and Zapotecan civilizations, as testified by the well known ruins of Mitla and Monte Alban.

Geologically this region is very interesting as it contains some features of all of the adjoining provinces. In the Tomellin Canyon in the north end of the valley are found gneisses which are considered to be pre-Paleozoic. On the western edge of the valley are pre-Paleozoic and Paleozoic schists and granites. Triassic shales and schists and Cretaceous limestones and shales occur in the western, northeastern, and central parts of the valley. In the Taviche mining district, various flows of andesites are seen. Farther south, near the Sierra del Labrador, there are intrusions of granodiorite, diabase, and andesites. Younger igneous rocks consisting of greenish rhyolitic tuffs occur in the central part of the valley. The ancient Indians used these tuffs to make the wonderfully carved walls of the Mitla temple. Recent deposits of travertine in the vicinity of Etla furnish quantities of the product commonly known as Mexican onyx (Tecali).

The mineral deposits of this region are well known. Narrow veins containing native gold are found in granites in the Peras district. Gold placer deposits on the western side of the valley were exploited by the ancient Indians and the gold was used to make jewels such as those unearthed at Monte Alban. In the andesites of the Taviche district are found veins containing high values in both silver and gold. In the mountains, in the valley, and in the near-by ranges, there are several mining districts and many mineral areas have been only slightly explored or exploited.

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DAWSON AND LARAMIE FORMATIONS IN SOUTHEASTERN PART OF DENVER BASIN, COLORADO[1]

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ABSTRACT

The Dawson arkose in the Castle Rock and Colorado Springs quadrangles, Colorado, is more than 2,000 feet thick and consists of arkosic conglomerate and sand. It merges northward into the Arapahoe and Denver formations along the foothills of the Front Range, where the beds stand vertically or dip steeply eastward on the west flank of the Denver Basin. The Dawson and Arapahoe formations along this belt overlie with erosional irregularity the finer-grained sands and shales of the Laramie formation, which is coal bearing. In the plains region—on the east side of the basin—where the beds dip gently westward into the basin, the upper part of the Dawson retains its coarsely conglomeratic nature, but the lower part consists chiefly of arkosic sands and dark shales and contains beds of lignitic coal, being thus not much dissimilar to the underlying Laramie upon which it rests with apparent conformity. The Laramie and Dawson formations, however, contain distinctive floras, some additional collections of which are recorded. Identifiable remains of *Triceratops* have been found in the lower part of the Dawson, but the upper part has not yielded fossils diagnostic of age. The United States Geological Survey now classifies the Dawson as Cretaceous and Eocene (?) in age, instead of Eocene as heretofore.

INTRODUCTION

The recently issued geologic map of Colorado, published by the United States Geological Survey, shows a much greater extent of the Dawson arkose than has appeared on previously published maps of the region. The location of the contact between the Dawson and the underlying Laramie formation is partly credited to unpublished reconnaissance mapping in eastern Colorado by the writers of this paper. The mapping was done chiefly in 1931 and partly in 1932. Inasmuch as no comprehensive report on this mapping is planned, it seems desirable to give the evidence for the position of the contact, as now shown on the Colorado geologic map, and describe briefly the nature and relations of the formations.

The area here discussed includes about 3,500 square miles in parts of Adams, Arapahoe, Elbert, El Paso, Lincoln, and Washington counties (Fig. 1) and lies in the southeastern part of the Denver Basin—a major structural depression in the Cretaceous rocks, the deepest part of which lies near Denver. The western flank of the basin

[1] Published by permission of the director of the United States Geological Survey. Manuscript received, July 17, 1936.

[2] United States Geological Survey.

is formed by the belt of steeply eastward dipping, vertical, or locally overturned beds along the foothills of the Front Range, but from the north, south, and west the Cretaceous rocks dip gently into the trough of the depression. The beds to which the name Dawson arkose has been applied crop out only in the southern part of the Denver Basin.

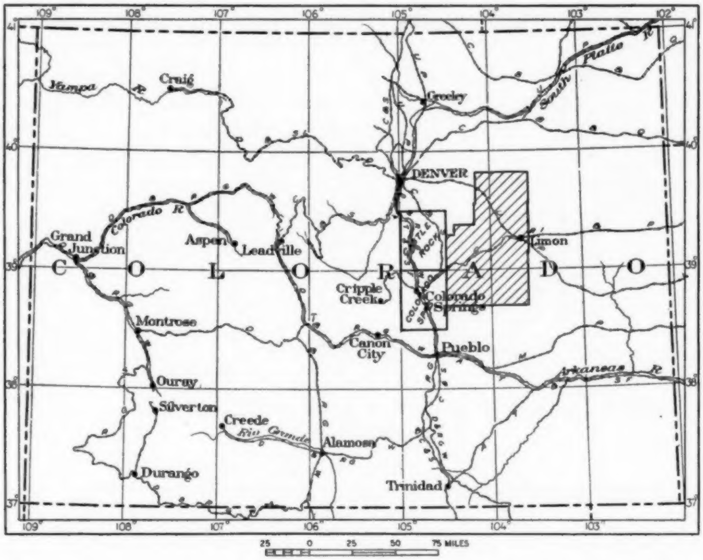


FIG. 1.—Index map of Colorado, showing area of this report and its relation to adjoining areas of United States Geological Survey folios.

The Dawson arkose was named by Richardson in the Castle Rock Quadrangle (Fig. 1) to include

> a complex mass of vari-colored and vari-textured arkosic conglomerate, sandstone, shale, subordinate carbonaceous deposits, and clay derived chiefly from the rocks of the Front Range and deposited under various continental conditions.[3]

This assemblage of beds has a maximum thickness of about 2,000 feet. The Dawson arkose was found by Richardson to merge laterally into both the Arapahoe formation and the overlying Denver formation, as earlier described in the vicinity of Denver farther north (Fig. 2).

[3] G. B. Richardson, "Castle Rock, Colorado," *U. S. Geol. Survey Atlas Folio 198* (1915), p. 7.

The Arapahoe formation[4] consists of grit and conglomerate derived chiefly from crystalline rocks, and sands and clays, the latter occurring mostly in the upper part. There is in places a definite basal conglomerate. The formation is about 600 feet thick. The overlying Denver formation was differentiated from the Arapahoe partly because of the extent to which the debris of andesitic rocks was found in it, particularly in the lower part, but occurring in diminishing amounts upward in the formation. The upper part of the Denver con-

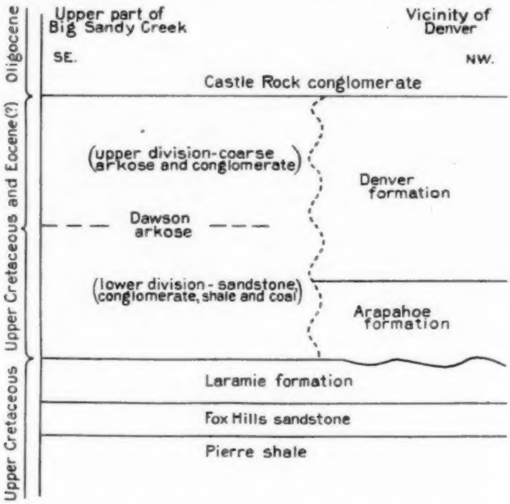


FIG. 2.—Diagram showing relation of Dawson arkose to Denver and Arapahoe formations.

sists largely of the debris of granitic and metamorphic rocks. The two formations were believed to be separated by an unconformity. Much doubt has subsequently been expressed as to the validity of the separation of the Arapahoe and Denver formations,[5] particularly since it has been shown that the vertebrate faunas and the floras are closely related and like those found also in the Dawson arkose.[6] Andesitic material similar to that found in the Denver has been found also in the Dawson arkose. In the northern part of the Castle Rock

[4] S. F. Emmons, Whitman Cross, and G. H. Eldridge, "Geology of the Denver Basin in Colorado," *U. S. Geol. Survey Mon. 27* (1896), pp. 151–201.

[5] J. H. Johnson, "The Geology of the Golden Area, Colorado," *Colorado School Mines Quart.*, Vol. 25, No. 3 (1930), p. 14.

[6] G. B. Richardson, *op. cit.*, p. 8.

Quadrangle, an andesitic member of that formation was differentiated and mapped[7] at an horizon that is the direct southern continuation of the Denver formation as mapped in the monograph on the geology of the Denver Basin. Later an andesitic member was recognized at the base of the Dawson arkose in the Colorado Springs Quadrangle[8] at an horizon presumably equivalent in part to the Arapahoe.

On the areal geologic map accompanying the report on the Denver Basin,[9] a considerable area east and northeast of Denver is shown as underlain by the Laramie formation. In the part of that area called the Scranton district, lying 10–15 miles east of Denver, the shale, sandstone, and coal beds were correlated with the "upper shaly division of the Laramie." In the course of reconnaissance during the mapping of the Castle Rock Quadrangle in 1910–1911, Richardson traced, on the plains east of Castle Rock, a zone of coal beds lying 900–1,200 feet above the base of the Laramie formation and carrying fossil leaves that were considered to be post-Laramie in age by the late F. H. Knowlton.[10] This coal-bearing zone Richardson traced to within 15 miles of Scranton and on stratigraphic evidence correlated the zone with the Scranton coals.

The localities at which Richardson's collections were made are shown on the map (Fig. 3 of the present paper), as are also localities in this region subsequently cited by Knowlton,[11] at which species of Denver age were collected.

At a somewhat later time, limited collections of plants identified as "having distinct affinities with the Raton" were made in the Bijou Creek drainage area[12] from beds then mapped as Laramie.

The stratigraphic position and geographic location of the boundary between the Dawson and Laramie formations thus remained undetermined in the plains region and, so far as the published record shows, the Laramie flora has not been collected east of its occurrence along the foothills and south of the South Platte River, although the sandstone and coal-bearing beds overlying the Fox Hills sandstone in the plains region have been known on other grounds to belong to the

[7] G. B. Richardson, *op. cit.*, p. 7.

[8] G. I. Finlay, "Colorado Springs, Colorado," *U. S. Geol. Survey Atlas Folio 203* (1916), p. 9.

[9] S. F. Emmons, Whitman Cross, and G. H. Eldridge, *op. cit.*, Pl. 3.

[10] G. B. Richardson, "Note on the Age of the Scranton Coal, Denver Basin, Colorado," *Amer. Jour. Sci.*, Vol. 43 (1917), p. 243.

[11] F. H. Knowlton, "The Flora of the Denver and Associated Formations of Colorado," *U. S. Geol. Survey Prof. Paper 155* (1930).

[12] W. C. Toepelman, "Preliminary Notes on the Revision of the Geological Map of Eastern Colorado," *Colorado Geol. Survey Bull. 20* (1924), p. 11.

Laramie formation. During the course of the writers' reconnaissance, the upper and lower contacts of the Laramie formation in the plains region were identified and mapped on lithologic features and in the formation, as thus delimited, collections of leaves indicative of Laramie age were obtained at a number of localities. The lithologic character, thickness, relations, and age of the Laramie and Dawson formations are described on the following pages, preceded by a brief description of the underlying Fox Hills sandstone, the highest marine Cretaceous formation of the region.

FOX HILLS SANDSTONE

The Fox Hills sandstone, as delineated on the accompanying map (Fig. 3), is a unit ranging from 200 to a little more than 300 feet thick, consisting, in the lower part, of buff or brown sandstone and sandy shale containing large, gray to brown, hard, sandy concretions and, in the upper part, chiefly of soft, poorly consolidated, white sandstone. The formation limits selected for reconnaissance mapping by the writers in 1931 correspond, in at least a general way, with the restricted definition of the Fox Hills in northeastern Colorado promulgated by the Rocky Mountain Association of Petroleum Geologists in 1932.[13] In the region shown on the map (Fig. 3), this formation and the basal part of the overlying Laramie formation are best exposed in the headwater tributaries of Beaver Creek, east of Agate on the Union Pacific Railroad.

In this vicinity, near the corner of Ts. 6 and 7 S., Rs. 57 and 58 W., the following section was measured and computed.

	Thickness *Feet*	*Inches*
Lower part of Laramie formation		
Clay, gray, with brown, sandy concretions		
Shale, black, carbonaceous	1	0
Clay and coal, dirty	0	6
Coal, dirty	0	7
Coal	1	2
Sand, white, soft; and clay, sandy	2	0
Shale, sandy, white	1	0
Shale, gray	2	0
Shale, sandy, hard, brown, carbonaceous	0	2
Shale, carbonaceous, brown	2	0
Shale, carbonaceous, black	1	0
Shale, carbonaceous, brown	14	0
Shale, carbonaceous, brown, with hard, brown, sandy concretions	1	0
	26	5

[13] T. S. Lovering, H. A. Aurand, C. S. Lavington, and J. H. Wilson, "Fox Hills Formation, Northeastern Colorado," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 16, No. 7 (1932), pp. 702–03.

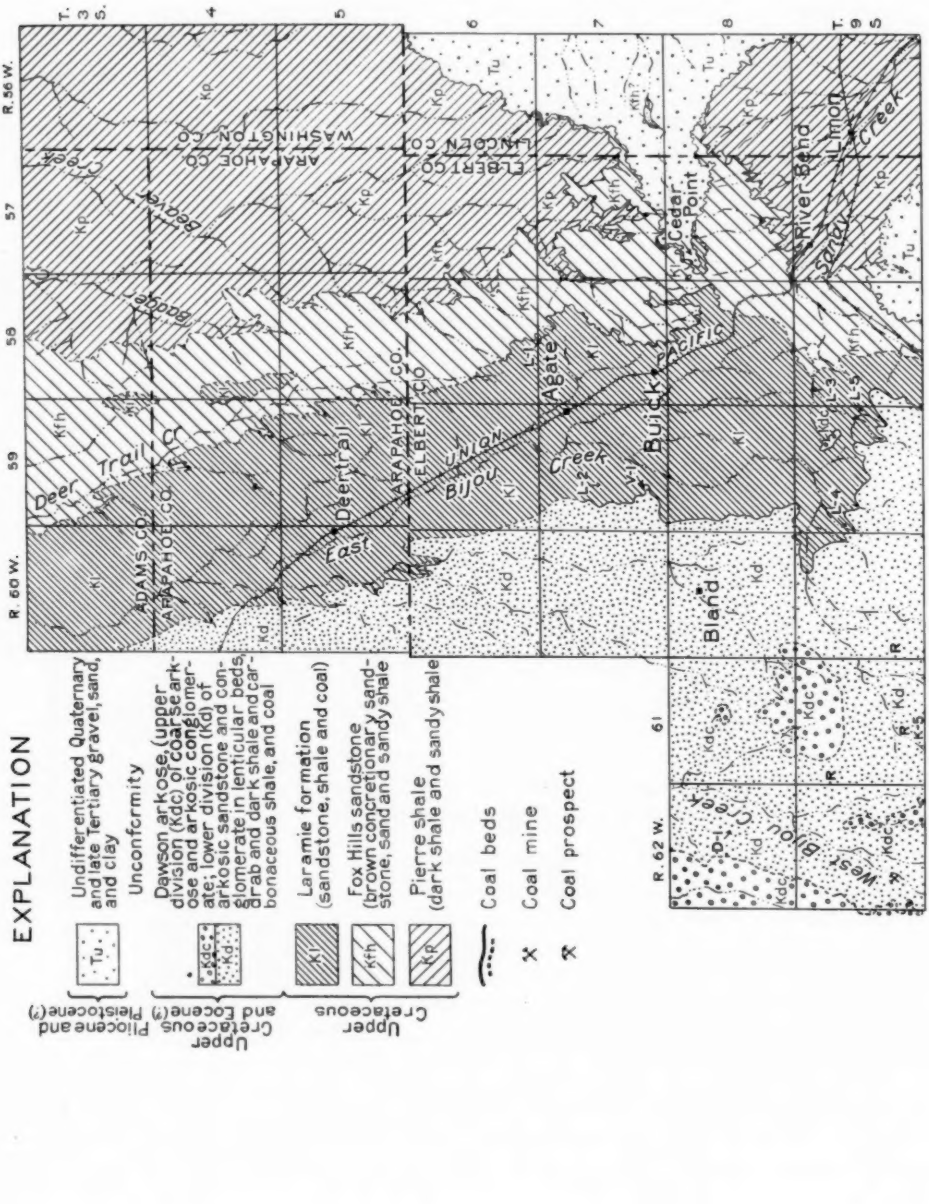
	Thickness Feet	Inches
Fox Hills sandstone		
Sand, white, soft, with a few discontinuous beds and lenses of hard, brown, cross-bedded sandstone at least 2 feet thick, contains some *Halymenites major Lesquereux*	70	
Sand, soft, yellow and white, some beds of gray clay, some large, hard, brown concretions, some hard, thin, yellow-weathering, calcareous concretionary beds	150	
J. B. Reeside, Jr., identified fossils collected from the upper part of this zone as *Nucula planimarginata, Anomia* sp., *Tancredia americana, Lunatia subcrassa, Cardium whitei, Mactra formosa, Fasciolaria (Piestochilus) culbertsoni,* and *Fasciolaria (Piestochilus) scarboroughi.* In a collection made from an horizon somewhat lower in the zone, he identified the following fossils: *Nucula planimarginata, Cardium whitei, Protocardia subquadrata, Mactra* sp., and *Dentalium gracile.* From a still lower zone were obtained specimens identified as *Nucula larimerensis.*		
Concretionary bed, yellow-weathering, sandy, calcareous	1–2	
Sand, gray, soft, and shale, sandy	85	
Concretionary bed, yellow-weathering, sandy, calcareous, extends over several square miles, but breaks into scattered lenses locally	1–2	
J. B. Reeside, Jr., identified fossils collected from this bed as *Yoldia evansi, Pholadomya* n. sp., and *Belemnitella bulbosa.*		
Sand, soft, earthy	5	
	312–314	
Base of Fox Hills—top of Pierre shale		
Shale, sandy, gray	12	
Concretionary bed, lenticular	1	
Shale, slightly sandy, gray		

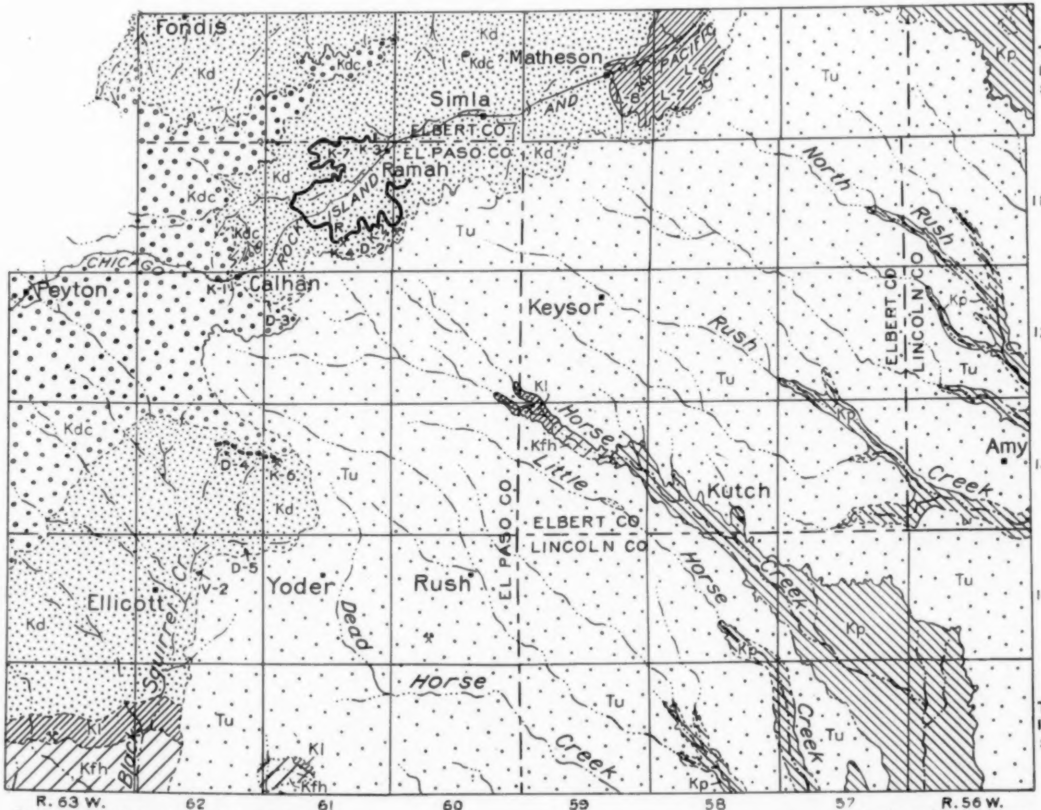
The top of the Fox Hills sandstone in the foregoing section was selected as the horizon above which carbonaceous shale and coal are found. This horizon, or one above which predominantly fresh- or brackish-water sandstone and shale appear, is the most convenient place to set the contact in view of the fact that continuous tracing of beds may never be possible in parts of the region. Locally there is some evidence to show that this lithologic change occurs at different stratigraphic levels from place to place.

LARAMIE FORMATION

The Laramie formation of this region is a rather homogeneous series of beds consisting chiefly of dark clays and shales, with some coal beds and tan or dark brown sandstones. The formation rests conformably and probably with intertonguing relationships on the Fox Hills. No instrumental measurements of the thickness of the Laramie were made, but a consideration of the approximate altitudes of the upper and lower contacts and of the probable dips indicates that the formation is 300–350 feet thick west of Buick and about the same east of Matheson.

Because exposures are scattered and small, no complete stratigraphic sections were measured. The nature of the formation can


EXPLANATION
Pliocene and Pleistocene(?)
Tu
Undifferentiated Quaternary and late Tertiary gravel, sand, and clay
Unconformity
Upper Cretaceous and Eocene(?)
Kdc
Kd
Dawson arkose, (upper division (Kdc) of coarse arkose and arkosic conglomerate; lower division (Kd) of arkosic sandstone and conglomerate in lenticular beds, drab and dark shale and carbonaceous shale, and coal
Upper Cretaceous
Kl
Laramie formation (sandstone, shale and coal)
Kfh
Fox Hills sandstone (brown concretionary sandstone, sand and sandy shale
Kp
Pierre shale (dark shale and sandy shale
Coal beds
Coal mine
Coal prospect
R. 56 W.
57
58
59
R. 60 W.
61
R. 62 W.
T. 3 S.
4
5
6
7
8
T. 9 S.
ADAMS CO.
ARAPAHOE CO.
WASHINGTON CO.
LINCOLN CO.
ELBERT CO.
Deer Trail Cr
Beaver Creek
Badger
East Bijou Creek
West Bijou Creek
Deertrail
Agate
Buick
Bland
Cedar Point
River Bend
Limon
Sandy Creek
UNION PACIFIC



Base from U.S. Geological Survey map of Colorado compiled in 1922

Geology by C. H. Dane and W. G. Pierce, 1932

FIG. 3.—Reconnaissance geologic map of southeastern part of Denver Basin, Colorado.

K. Approximate position of localities at which collections of leaves regarded by F. H. Knowlton as Denver in age were obtained, as recorded in *U. S. Geol. Survey Prof. Paper 155*, "The Flora of the Denver and Associated Formations of Colorado." Numbers refer to localities described in that publication as follows: 1, Rice's pit; 2, Red Hill; 3, ½ mile west of Ramah; 4, ½ mile east of Purdon mine; 5, 1 mile south of Ramah oil well; 6, Mosby's mine; 7 Coal gulch.

R. Approximate position of localities at which collections of leaves regarded by F. H. Knowlton as Denver in age were obtained as recorded by G. B. Richardson in "Notes on the Age of the Scranton Coal, Denver Basin, Colorado," *Amer. Jour. Sci.*, Vol. 43 (1917).

D. Localities at which collections of leaves regarded by R. W. Brown as Denver in age were obtained by writers. Numbers (D-1 to D-5) refer to lists in text of this paper.

L. Localities at which collections of leaves regarded by R. W. Brown as Laramie in age were obtained by writers. Numbers (L-1 to L-8) refer to lists in text of this paper. Collection L-8 is not definitely indicative of Laramie age.

V. Localities at which dinosaur bones have been collected from Dawson arkose. Numbers (V-1 and V-2) refer to text of this paper.

therefore be best described by recording the observations made at several localities.

A section of the basal part of the Laramie formation near the corner of Ts. 6 and 7 S., Rs. 57 and 58 W., is given in the preceding measured section. About 25 feet higher than the top of that section, is a clinker bed, in the NW. ¼ of Sec. 3, T. 7 S., R. 58 W., and coal and carbonaceous shale are conspicuous in this vicinity. For some distance farther north the position of the Laramie-Fox Hills contact is fairly well established by the occurrence of carbonaceous shale or coal a short distance above soft and hard sandstone in the SW. ¼ of Sec. 30, T. 5 S., R. 58 W., the N. ½ of Sec. 13, T. 5 S., R. 59 W., and the NW. ¼ of Sec. 35, T. 4 S., R. 59 W. The base of the Laramie is exposed in a small gully near the line between Secs. 9 and 10, T. 4 S., R. 59 W., where green and gray clay rests on a hard, gray sandstone bed which caps soft, white, cross-bedded sand. Carbonaceous clays and coal are exposed in Secs. 16 and 21 of the same township.

Outcrops of carbonaceous shale and coal in Secs. 19 and 30, T. 4 S., R. 58 W., and carbonaceous shale in the NW. ¼ of Sec. 5, T. 5 S., R. 58 W., appear to represent an outlier of the Laramie formation east of Deer Trail Creek, but these outcrops seem to be lower in the stratigraphic section than sandstone beds assigned to the upper part of the Fox Hills in Secs. 19 and 20, T. 5 S., R. 58 W. If so, the lithologic contact between the Laramie and the Fox Hills has dropped somewhat toward the north.

Another small outlier of the Laramie, east of Deer Trail Creek, is indicated by outcrops of coal and carbonaceous shale interbedded with white sand in the NW. ¼ of Sec. 30, T. 3 S., R. 58 W. The contact of the Laramie and the Fox Hills is also exposed west of Deer Trail Creek in the NW. ¼ of Sec. 29, T. 3 S., R. 59 W., but farther north the contact can be drawn only approximately. Sandstone assigned to the Fox Hills crops out at several places along the east bank of Deer Trail Creek. In the SE. ¼ of Sec. 31, T. 1 S., R. 59 W., a collection of fossils from an outcrop of this sandstone was examined by Reeside. It included *Tellina equilateralis*, *Cardium whitei*, *Melania?* sp., and shark teeth, an assemblage suggesting marine conditions, but contâined also crocodile teeth and an abundance of *Ostrea glabra*, which suggest that the conditions were not truly marine, but possibly lagoonal.

The quality of the coal in the Laramie of this northern part of the region may be judged by an analysis (U. S. Bur. Mines Lab. No. 94619) made in 1923 of a sample from the strip pit of Matilda Stimson near Buick, which showed a heating value of 6,650 B.T.U. as received.

The basal part of the Laramie is well exposed in the vicinity of Cedar Point, in the northern part of T. 8 S., Rs. 57 and 58 W. Exposures of the Laramie are less satisfactory south of the Union Pacific Railroad, but in the SW. ¼ of Sec. 5, T. 9 S., R. 58 W., the following section was measured near the base of the formation.

	Thickness Feet	Thickness Inches
Top of section		
Shale, carbonaceous, black	6	
Shale, brown, with plant fragments		6
Shale, carbonaceous, black and lignite, dirty	6	
Shale, brown, with plant fragments	1	6
Shale, light gray, and thin lenses of yellow sandstone	2	
Shale, gray	3	6
Shale, gray brown; sandstone, shaly, yellow; brown sandstone concretions	1	
Shale, carbonaceous, black	4	
Base not exposed		

Above these beds lie drab to greenish gray shale or clay containing brown ferruginous concretions, which are exposed in the NW. ¼ of Sec. 7, T. 9 S., R. 58 W. Somber dark shale lies above these greenish shales and is exposed for some miles farther west, but in the NW. ¼ of Sec. 18, T. 9 S., R. 59 W., below dark carbonaceous clay containing a probable Laramie species of plant, there are yellow crumbly sandstones and hard, gray, calcareous sandstones.

Coal beds in the middle or upper part of the Laramie formation have been mined south of the Rock Island Railroad, in T. 10 S., Rs. 57 and 58 W. The following section was measured at the Barker mine, an open cutbank in the SE. ¼, NW. ¼ of Sec. 21, T. 10 S., R. 58 W.

	Thickness Feet	Thickness Inches
Top of section		
Shale, gray, with some sandstone lenses		
Sandstone, gray to tan, soft	3	
Shale, carbonaceous, brown	1	6
Coal, dirty, with carbonaceous shale in upper part	1	3
Coal	4	0
Parting, coaly shale	0	3
Coal	8	
Base not exposed		

A section of the coal in this strip was also measured in 1914 by M. R. Campbell as follows.

	Thickness Feet
Roof	
Coal	2
Parting	
Coal	5
Parting	
Coal	4
Floor	

An "as received" analysis (U. S. Bur. Mines Lab. No. 19902) of the coal of the 5-foot bed gave a heating value of 6,147 B.T.U.

Another section measured by Bauer and Litchfield in the center of the Wright strip pit of the Wright Barker mine is as follows.

	Thickness	
	Feet	*Inches*
Roof		
Coal	3	6
Parting		
Coal	3	0
Sandstone		10
Coal	3	6
Coal	4	6
Floor		

A sample (U. S. Bur. Mines Lab. No. A2438) gave a heating value of 6,890 B.T.U.

At an inclined drift in the NE. ¼ of Sec. 24, T. 10 S., R. 59 W., coal is reported at a depth of 57 feet below the surface. The bed is said to be 5 feet thick with 2 feet of bone and dirty coal overlying it. Another sloping shaft in the NW. ¼ of the same section encountered a coal bed 9 feet thick. Judged from the reported attitude of the coal in these mines, it seems probable that there has been some structural warping or slight deformation in this area. A sample of coal from this mine, obtained in 1923 from the face of the first north entry, 480 feet in from the opening, yielded on an "as received" analysis (U. S. Bur. Mines Lab. No. 94617) a heating value of 7,070 B.T.U. In 1924, a section in the No. 2 room off the first north entry gave a coal thickness of 9 feet, 2 inches, with a discontinuous parting 9 inches above the base. The upper 8 feet, 5 inches of the coal, when analyzed (U. S. Bur. Mines Lab. No. A3449), showed a heating value of 7,130 B.T.U. as received. The Laramie, above the horizon at which these coals occur, consists chiefly of gray, somber, and nearly black shales and sandy shales with rusty ellipsoidal concretions. Thin beds of calcite cone-in-cone concretions occur locally and fragments of silicified wood are rather abundant.

South of the Chicago, Rock Island and Pacific Railroad the rocks are widely concealed by the sand and gravel cover of the High Plains. There are small exposures of the Laramie, however, in the upper part of the valley of Horse Creek. A bed of dirty coal, about 3 feet thick, with a shale floor and roof, has been prospected near the center of Sec. 6, T. 13 S., R. 59 W., and somber shales of Laramie aspect are exposed in the SW. ¼ of Sec. 5 of the same township. Exposures of soft cross-bedded sand, believed to be the uppermost part of the Fox Hills, occur in the SE. ¼ of Sec. 9, of the same township.

A coal mine southwest of Rush, probably in the southwestern part of T. 14 S., R. 60 W., is believed to have worked a coal bed near the base of the Laramie.[14]

The lower part of the Laramie and the upper part of the Fox Hills are exposed over a small area in the southwestern part of T. 15 S., R. 61 W. Thin coal beds, shales, and carbonaceous clays at or near the base of the Laramie are exposed in the SE. ¼ of Sec. 29, and brown sandstone, believed to be the top of the Fox Hills, lies a short distance below. There is an exposure of 20 feet of massively bedded, light tan Fox Hills sandstone in the NE. ¼ of Sec. 32. The lower part of the Laramie is also exposed in the NE. ¼ of Sec. 20, T. 15 S., R. 62 W., and a mine has exploited Laramie coal in Sec. 21, T. 15 S., R. 63 W.

The lower part of the Laramie, near the middle of the W. ½ of Sec. 20, T. 15 S., R. 63 W., contains shale, mudstone, a thin bed of coal, and soft, massive, white and gray sandstone. The Fox Hills sandstone below it is buff to tan, with a bed at the top about 1 foot thick of slightly harder, crumbly, brown sandstone containing a few casts of *Halymenites*. In the adjoining Colorado Springs Quadrangle, the Laramie is described as consisting of fine-grained quartz sandstone and some black shale and thin seams of coal, the formation having a thickness of 250–300 feet.[15]

Collections of leaves were made from the Laramie formation at several localities. These collections were examined for the writers by R. W. Brown, of the Geological Survey, and he regards them as indicative of Laramie age. The localities from which the collections were made are shown by numbers on the map (Fig. 3), and the identifications are listed as follows.

PLANTS FROM LARAMIE FORMATION

Locality L-1, in the N.W. ¼ of Sec., 3, T, 7 S., R. 58 W.
- *Ficus arenacea or navicularis*
- *Ficus post-trinervis*
- *Sabal montana*
- *Zizyphus hendersoni*

Locality L-2, in the S.W. ¼ of Sec. 16, T. 7 S., R. 59 W.
- *Dammara* cone scales
- ? palm petiole

Locality L-3, in the S.E. ¼ of Sec. 6, T. 9 S., R. 58 W.
- *Equisetum* like *E. perlaevigatum*
- *Cyperacites* sp.
- *Pistacia hollicki*
- One seed—indeterminable

[14] R. C. Coffin, "Ground Waters of Parts of Elbert, El Paso, and Lincoln Counties," *Colorado Geol. Survey Bull. 26* (1921), Fig. 1.

[15] G. I. Finlay, "Colorado Springs, Colorado," *U. S. Geol. Survey Atlas Folio 203* (1916), columnar section.

Locality L-4, in the N.W. ¼ of Sec. 18, T. 9 S., R. 59 W.

Dammara cone scales

Locality L-5, in the N.E. cor. of Sec. 24, T. 9 S., R. 59 W.

Betula sp.
Salix wyomingensis
Ficus post-trinervis
Ficus impressa
Ficus arenacea
Juglans leconteana
Laurus lanceolata

Locality L-6, in the SE. ¼, NW. ¼ of Sec. 21, T. 10 S., R. 58 W.

Platanus platanoides
Myrica oblongata
Salix sp.

Locality L-7, in the N.W. ¼, SW. ¼ of Sec. 29, T. 10 S., R. 58 W.

Cyperacites hillsii
Pistacia hollicki

A collection from locality L-8, in the SE. ¼ of Sec. 26, T. 10 S., R. 59 W. was regarded by Brown as not definitely indicating either Laramie or Dawson age; it included the following forms.

Laurus lanceolata
Salix myricoides
Rhamnus or *Cornus* sp.
Phyllites n. sp.

DAWSON ARKOSE

The contact between the Dawson and Laramie formations as drawn on the map (Fig. 3) is based almost entirely on the gross lithologic differences between the formations. The contact can be drawn with most assurance across the valley of Big Sandy Creek and in the upper part of the drainage system of East Bijou Creek and its tributaries, in a belt where outcrops are most abundant, lying chiefly in R. 59 W. and extending through Ts. 6–10 S. The lower part of the Dawson includes arkosic sands and lenticular beds of conglomerate in addition to sandy and carbonaceous and drab clay shales. The upper part of the Laramie, on the whole, contains not so many beds of sand as the lower part, contains no conglomerate, and consists very largely of gray shales with numerous small flattened ferruginous concretions. Individual outcrops of the formations are, however, not distinctive and although it is believed that the contact as drawn represents a continuous contact at one horizon, the evidence in the field does not preclude the possibility that the observed lithologic change occurs at different horizons from place to place.

Crumbly, yellow, cross-bedded, arkosic sandstone, believed to be the basal bed of the Dawson, overlies gray sandy shale with numerous leaf impressions in the SW. ¼ of Sec. 17, T. 7 S., R. 59 W. Outcrops of drab to nearly black shale with large shattered ferruginous concre-

tions, typical of the upper part of the Laramie, occur about a mile farther east in the SW. ¼ of Sec. 16.

About 2 miles south of these localities, in the vicinity of the corner of Secs. 28, 29, 32, and 33, soft, yellow, crumbly sand overlies extensive exposures of drab, brown, black, and white clays, and carbonaceous shales containing poor leaf material. The sand shows an early stage of the formation of large round concretions with radiating calcite beginning to form on the surfaces of the concretions. Hard, gray, calcareous sandstone concretions are not uncommon farther south in the lower part of the Dawson. A portion of a bone was collected from the soft sand in the NW. ¼ of Sec. 33, T. 7 S., R. 59 W. (locality V-1 in Fig. 3). Concerning this specimen, C. W. Gilmore reports

The specimen is the lower or distal end of a femur of a Hadrosaurian dinosaur. The genus cannot be determined. . . . No limit is given to its precise geologic age.

Soft, yellow, crumbly sand with hard, gray, calcareous sandstone concretions overlies gray and drab shale with small, shattered, ferruginous concretions in the SE. ¼ of Sec. 18, T. 8 S., R. 59 W. Therefore, this exposure is believed to show the Dawson-Laramie contact, but at this place there is a suggestion of transitional relations with local beds and lenses of crumbly yellow sand below the continuous bed of sand at the base of the Dawson. The lithologic change from drab and locally plant-bearing shale upward to crumbly yellow sand is exposed also in the NE. ¼ of Sec. 6, T. 8 S., R. 59 W., the SW. ¼ of Sec. 2, T. 9 S., R. 60 W., and the northern part of Sec. 18, T. 9 S., R. 59 W.

The basal 50 feet of the Dawson in the NW. ¼ of Sec. 31, T. 9 S., R. 58 W., includes coarse arkosic sandstone, greenish argillaceous sandstone, and some black shale, the upper part of the underlying Laramie consisting as elsewhere, of drab shale with rusty-weathering concretions. The lowest 100 feet of the Dawson is exposed north of Matheson, in Secs. 11–14, T. 10 S., R. 59 W., and in this vicinity includes some lenses of light gray, cross-bedded, coarse, arkosic conglomerate in which one pebble of quartzite was observed to have a maximum dimension of nearly 4 inches. The conglomerate lenses are embedded in drab shale or clay with rusty-weathering concretions, some of which apparently occur as pebbles in the conglomerate. In the upper part of the exposure is a prominent bed of black carbonaceous shale about 3 feet thick, which is underlain by white clay and overlain by olive-drab clay. Above the beds described and in the SW. ¼ of Sec. 1, T. 10 S., R. 59 W., are outcrops of greenish gray, crumbly sandstone and

cross-bedded conglomerate composed chiefly of pellets of micaceous, yellowish brown clay as large as 1 inch in maximum dimension.

No conglomerate was observed south of Matheson in the basal part of the Dawson, which consists largely of arkosic sand at the exposures examined. A few miles south of Matheson, the Dawson-Laramie contact passes beneath the later Tertiary cover of the High Plains and is thus concealed for many miles farther south. The contact should appear from beneath the later Tertiary cover in T. 15 S., Rs. 62 and 63 W., but exposures are virtually lacking and the contact as drawn is more or less hypothetical.

The lowest satisfactory exposures of the Dawson in the southwestern part of the area shown in Figure 3 are in the northeastern part of T. 14 S., R. 62 W., northeast of Ellicott, where arkosic sand containing clay pellets, sandy shale, and some carbonaceous shale are exposed. Some fragile reptilian bones were found in the SE. ¼ of Sec. 9, T. 14 S., R. 62 W., embedded in a clay pellet bearing arkosic sand that fills a small channel-like depression cut in a gray clay. The collection included a group of attached vertebrae, several limb bones and ribs, and a sacrum with attached ilia. According to C. W. Gilmore, the sacrum and attached ilia are in size and all other characteristics, so far as the preservation of the specimen permits of comparison, in full accord with the corresponding bones of *Triceratops*, and Gilmore feels that the definite identification of the specimen as *Triceratops* is fully justified.

Farther north in the NW. ¼ of Sec. 14, T. 13 S., R. 62 W., and at a somewhat higher horizon, arkosic and micaceous sandstone and leaf-bearing shale are exposed and in the southern part of Sec. 11 there is a coal bed 18 inches thick in a section composed chiefly of shale. Somewhat above this shale zone and in the western part of Sec. 11 are outcrops of massive to cross-bedded crumbly tan sandstone. Near or at the horizon of the coal bed described, Mosby's mine exploited coal in the NE. ¼, SE. ¼ of Sec. 18, T. 13 S., R. 61 W. At this mine a shaft encountered the following section.[16]

	Thickness	
	Feet	*Inches*
Roof, sandstone		
Coal	1	2
Shale		1
Coal	1	6
Shale		3
Coal	1	8
Floor, shale		

The coal is of subbituminous grade, with a reported heating value

[16] C. W. Cooke, unpublished notes (1910).

of 7,826 B.T.U., as received. Above it in the NE. ¼ of Sec. 18 and also in the SW. ¼ of Sec. 1, T. 13 S., R. 62 W., are outcrops of quartzite conglomerate interbedded with soft sandstone. These outcrops of conglomerate lie near the base of the upper conglomeratic part of the Dawson arkose.

Coal near the top of the lower shaly part of the Dawson arkose is also exposed in the valley of Big Sandy Creek, chiefly in T. 11 S., R. 61 W. The following section was exposed in the NW. ¼ of Sec. 30, T. 11 S., R. 60 W., in an old mine.

	Thickness	
	Feet	*Inches*
Roof, shale and bony coal		
Coal, in streaks, dirty	1	9
Parting, clay and bone		4
Coal	4	4
Floor, shale, brown		

The Purdon mine in the NW. ¼, SE. ¼ of Sec. 27, T. 11 S., R. 61 W., probably worked coal from the same bed as did a small prospect pit in Sec. 3 of the same township. The coal has not been traced north of this locality. Coal was noted in the SE. ¼ of Sec. 8, T. 10 S., R. 61 W., and the Janner mine in Sec. 29, T. 9 S., R. 62 W., 1 mile north of Fondis, has exploited coal which lies at least in the same general zone. Two analyses of coal have been recorded from the Janner mine. From the face of the main entry, 375 feet from the opening, an analysis (U. S. Bur. Mines Lab. No. 94618) made in 1923 shows a heating value of 5,860 B.T.U. In room 17, 270 feet from the bottom of the slope, the following section was measured.

	Thickness	
	Feet	*Inches*
Roof		
Coal	2	1¼
Parting		2
Coal	4	2½
Floor, coal (estimated thickness)	12	6

The analysis of the coal measured showed a heating value of 6,700 B.T.U. (U. S. Bur. Mines Lab. No. A47114).

Coal at the same general horizon may be represented by the clinker observed in the NW. ¼ of Sec. 16, T. 9 S., R. 62 W.

The outcrops described indicate the variability of lithologic composition of the lower part of the Dawson arkose in the region under consideration. Although it contains arkosic sand and locally arkosic conglomerate at the base and lenses and beds of arkose, quartzite conglomerate, and clay-pellet conglomerate at higher levels, it contains, particularly in its upper portion, a goodly percentage of shale, clay, and carbonaceous beds. The lithologic character indicates dep-

osition in stream channels, river flood plains, and marshes. Although the basal contact is locally sharp, there is at a few localities a suggestion of transition into underlying beds of slightly different lithologic character, that carry a Laramie flora. There is apparently no angular discordance between the two formations.

An examination of a few samples of sandstones from the lower part of the Dawson shows that they contain a very high percentage of angular grains of orthoclase feldspar, a lesser percentage of quartz grains, and a small amount of biotite, muscovite, and hornblende. They evidently represent the disintegration of granitic rocks. The most highly feldspathic sandstones have a crumbly consistency due to the decomposition of the feldspar grains to clay.

Judged from the driller's record of the A. A. Rollestone Company's Virgil Ullom No. 1 well in the NW. ¼, SW. ¼, SE. ¼ of Sec. 9, T. 12 S., R. 62 W., which encountered the top of the Fox Hills sandstone at about 1,450 feet, the thickness of the lower argillaceous and sandy part of the Dawson arkose may be about 1,000 feet.

On the accompanying map (Fig. 3) are shown the localities where leaves of the Denver flora have been collected, as recorded in previous publications,[17] and also the localities at which additional collections of the Denver flora were made by the writers. The identifications of this additional material by R. W. Brown are listed as follows.

PLANTS FROM DAWSON ARKOSE

Locality D-1, in the SE. ¼ of Sec. 15, T. 8 S., R. 62 W.

Juglans denveriana
Quercus viburnifolia
Platanus sp., probably *aceroides*

Locality D-2, in the NE. ¼ of Sec. 25, T. 11 S., R. 61 W., which is either near or at locality K-2.

Paloreodoxites plicatus
Geonomites tenuirachis
Juglans denveriana
Sapindus berryana
Prunus denverensis
Rhamnus cleburni
Platanus sp.
Viburnum sp.
Ficus sp.

Locality D-3, in the NW. ¼ of Sec. 7, T. 12 S., R. 61 W.

Juglans denveriana
Pterocarya? retusa
Artocarpus pungens
Laurus primigenia
Prunus denverensis

[17] G. B. Richardson, "Note on the Age of the Scranton Coal, Denver Basin, Colorado," *Amer. Jour. Sci.*, Vol. 43 (1917).
F. H. Knowlton, "The Flora of the Denver and Associated Formations of Colorado," *U. S. Geol. Survey Prof. Paper 155* (1930).

Viburnum richardsoni
Platanus sp., probably *aceroides*

Locality D-4, in the NW. ¼ of Sec. 14, T. 13 S., R. 62 W.
Sabalites grayanus
Geonomites tenuirachis
Juglans denveriana
Platanus sp., probably *guillelmae*
Cornus impressa

Locality D-5, in the SW. ¼ of Sec. 1, T. 14 S., R. 62 W.
Platanus sp., probably *reynoldsii*
Cornus impressa

Overlying the leaf-bearing and carbonaceous beds of the Dawson and their associated arkosic sands and conglomerates is a notably different phase of the formation, consisting chiefly of white or gray conglomerates of quartzitic or granitic pebbles. Although the upper conglomeratic part of the formation was not studied in detail, the approximate base of this more coarsely conglomeratic division of the Dawson was mapped and is shown in Figure 3.

RELATIONS BETWEEN LARAMIE AND DAWSON

The rocks now assigned to the Dawson, Denver, and Arapahoe were formerly conceived to overlie a great unconformity, and the presence of pre-Cambrian pebbles in the basal conglomerate of the Arapahoe was thought to show that 14,000 feet of sedimentary rocks in the Front Range region farther west had been removed after the deposition of the Laramie.[18] Later work[19] has indicated that parts of the Front Range region were probably rising throughout the Cretaceous, with parts of it subject to erosion during that period and probably earlier. Therefore, the removal of much of the cover of sedimentary rocks originally overlying the pre-Cambrian rocks in the Front Range region may have occurred before the deposition of the Laramie rather than in a period of post-Laramie uplift and erosion. The sands of the Laramie are in part arkosic,[20] and quartz pebble conglomeratic beds are not uncommon in it. Pebbles containing Pennsylvanian fossils are reported in the underlying Fox Hills and their source considered to be exposed Pennsylvanian rocks.[21] A likely source is the rising Front Range element. In addition to such evidence, later examination of the contact between the Laramie and Dawson

[18] S. F. Emmons, Whitman Cross, and G. H. Eldridge, "Geology of the Denver Basin in Colorado," *U. S. Geol. Survey Mon. 27* (1896), p. 209.

[19] T. S. Lovering, "Geologic History of the Front Range, Colorado," *Colorado Sci. Soc. Proc.*, Vol. 12, No. 4 (1929), pp. 87–94.

[20] T. S. Lovering, *op. cit.*, p. 90.

[21] F. O. Jones, "Significance of Chert and Flint Pebbles in the Fox Hills Formation of Colorado," *Jour. Colorado-Wyoming Acad. Sci.*, Vol. 1, No. 6 (1934), p. 33.

and Arapahoe in the foothills belt has failed to disclose anywhere angular unconformity between the two formations and it has become clear that apparent variations in the thickness of the Laramie in this belt may be due to local lack of definite evidence about the position of the upper contact and consequently variable assignments of beds to the formation from place to place. It has already been pointed out that the coarseness of detrital material in the basal parts of the Arapahoe and Dawson indicates a high stream gradient in the foothills belt,[22] and that the observed erosional irregularities are those expectable at the base of stream-channel deposits.

Although the initiation of Dawson sedimentation in the plains region described in this paper shows a definite coarsening of the clastic sediments, they are much finer than those of the foothills belt. Carbonaceous shales and coals testify to stream gradients sufficiently low to permit at times the formation of extensive swampy tracts. Not only is evidence of angular unconformity lacking, but there is locally, at least, a suggestion of transitional relations across the contact. The physical change in conditions of deposition from Laramie to Dawson must have been slight in the present plains region. It may be noted that such analyses of the Laramie and Dawson coals as are available do not show significant differences.

Nevertheless, the change in flora from Laramie to Dawson time appears to have been large, and since the flora of each formation is extensive and rather well diversified, this is somewhat surprising in view of the slight physical evidence for extensive environmental changes. The physical evidence seems to suggest that there was a gradual change from the coastal swamps of the retreating Cretaceous sea to the flood-plain, swamp and river-channel deposits of the lower part of the Dawson. The much sharper change in lithologic character in the foothills belt suggests, however, that there was an abrupt rising of the Front Range Highland, which was continued at a rapid rate and this uplift may have resulted in a rather sharp climatic change in the direction of reduction of rainfall or change in its seasonal abundance. If such changed conditions of moisture supply or temperature are the cause of the change in flora, it seems that there should be transition floras, unless there was a time lapse between the deposition of the Laramie and the Dawson, which is not indicated by the physical evidence. An examination of the map (Fig. 3) shows that there is a rather wide belt of the basal Dawson beds in the plains region from which collections have not yet been obtained. The collection previously listed from the SE. ¼ of Sec. 26, T. 10 S., R. 59 W., from beds

[22] T. S. Lovering, *op. cit.*, p. 91.

included in the top of the Laramie, was not regarded as definitely indicating either Laramie or Dawson age. More intensive collecting at more carefully determined stratigraphic horizons may result in the determination of differences in the flora at various levels in the Dawson.

AGE OF DAWSON ARKOSE

The proper age assignment of the Dawson arkose has been in debate for many years, as has the age assignment of many of the sedimentary formations of the Rocky Mountain and Northern Great Plains region, which occupy the same general position in the stratigraphic section—that is, near the close of the Cretaceous or in the early part of the Eocene. It has become increasingly clear that these formations were laid down as fluviatile and coastal plain deposits as a result of the uplift of the Rocky Mountain system that began before the close of the Mesozoic and continued into the Tertiary. The sediments which were deposited are laterally and vertically heterogeneous and in part, at least, were laid down in separate basins of deposition. The precise correlation of the distinguishable stratigraphic units in the several areas of exposure in the Rocky Mountains and Great Plains is yet to be effected, but progress has been made toward this correlation, primarily by the gradual collection and study of fossil vertebrate remains in the various formations. The amount of faunal evidence available is still scanty and evolutionary changes of time significance are probably in some measure obscured by the insufficiently evaluated effects of migration and locally different environmental conditions. Nevertheless, evidence has accumulated which shows that the uplifts in the Rocky Mountain region which caused the deposition of the continental formations occurred at different times in different places, that in most places there was more than one period of uplift and folding, and that at no one period was there a diastrophic movement of sufficient magnitude and geographic extent to warrant its selection as the boundary between the Mesozoic and Tertiary.

Accordingly, the division between the Cretaceous and Eocene in the Rocky Mountains and Great Plains must be based on the fossil evidence available, with the recognition that it may thus in some places fall within an otherwise inseparable lithologic unit. Fortunately for the purpose of a correlation thus based on fossil evidence, the Lance formation of South Dakota contains the Cannonball marine member, the fauna of which is regarded as definitely Cretaceous in age. According to the classification adopted by the United States Geological Survey (December 16, 1935), the Cannonball member

is considered to be Cretaceous in age, and accordingly, therefore, the *Triceratops*-bearing beds of the underlying part of the Lance and of other formations are also considered to be Cretaceous. This classification is still to some extent contradictory to the evidence of the floras, for the non-marine beds equivalent to the Cannonball member contain a flora of Eocene aspect.[23] The contradiction between the evidence afforded by the floras and faunas is not now, however, as great as heretofore, because the flora of much of the *Triceratops*-bearing beds has recently been accepted as Cretaceous in age.

The Cretaceous age of the lower part of the Dawson arkose is determined by the occurrence in it of ceratopsian remains, some of which are definitely referable to *Triceratops*. A re-examination of the fossil plants, which occur also in the lower part of the formation, has been partly completed by R. W. Brown, but he is not prepared at this time to reach a definite conclusion as to the age aspect of the flora. In the upper part of the Dawson arkose, fossils are almost lacking. From the middle part of the formation, at a locality in the Colorado Springs Quadrangle (Sec. 12, T. 13 S., R. 65 W., at the railroad crossing 1 mile southwest of Falcon), Richardson[24] obtained a small collection of leaves which, in the opinion of the late F. H. Knowlton, slightly suggests the flora of the Green River formation. Although in Knowlton's opinion this suggestion was too indefinite to be of much use, it is interesting as an indication of the possibility that the upper part of the Dawson may contain a flora younger than that represented by the extensive collections from the lower part. In the Denver Basin the next youngest formation above the Dawson is the Castle Rock conglomerate, of Lower Oligocene age.[25] Therefore, the upper parts of the Dawson and Denver formations may possibly include beds of Eocene age. Accordingly, the United States Geological Survey now classifies these two formations as Cretaceous and Eocene (?).

[23] R. W. Brown, personal communication.

[24] G. B. Richardson, "Castle Rock, Colorado," *U. S. Geol. Survey Atlas Folio 198* (1915), p. 8.

[25] G. B. Richardson, *op. cit.*, p. 9.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 20, NO. 10 (OCTOBER, 1936), PP. 1329-1341, 1 FIG., 2 PLATES

ORDOVICIAN FOSSILS FROM UPPER PART OF TYPE SECTION OF DEADWOOD FORMATION, SOUTH DAKOTA[1]

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ABSTRACT

In the northern Black Hills, Middle (?) Ordovician fossils have been found to occur throughout approximately 70 feet of shale and siltstone beds immediately below the typical Whitewood dolomite. These beds and their faunas are discussed, and it is concluded that the strata involved should be included tentatively, at least, with the overlying Whitewood formation (Ordovician), rather than with the underlying Deadwood formation (Cambrian) as has been done heretofore.

INTRODUCTION

In 1928, Barragy found Ordovician fossils in the upper part of the type section of the Deadwood formation in the Black Hills. Some of the conodonts obtained were sent to Branson and Mehl, and they[3] have recently indicated that these are Black River-Trenton in age. However, their brief mention is the only record of the discovery that has appeared in the literature, and it seems to merit amplification. During the past summers the writers have visited the locality several times, carefully studied the beds in question, and collected many additional fossils. Part of their field expenses were paid from research funds of the Graduate College of the State University of Iowa, and they wish to express their sincere appreciation for this favor.

PREVIOUS WORK

As is well known, the entire Deadwood formation has for some time been placed in the Cambrian. As early as 1880, Newton[4] discussed the Lower Paleozoic strata of the Black Hills and correlated them with the "Potsdam," which he regarded as a subdivision of the

[1] Manuscript received, June 15, 1936.

[2] State University of Iowa. Barragy's present address is 2502 Hazard Street, Houston, Texas.

[3] E. B. Branson and M. G. Mehl, "Conodont Studies," *Missouri Univ. Studies*, Vol. 8 (1933), pp. 8, 21—see also "Errata."

[4] Henry Newton and W. P. Jenney, "Report on the Geology and Resources of the Black Hills of Dakota," *U. S. Geog. and Geol. Survey Rocky Mountain Region* [*Powell*] (1880), pp. 80–107.

"lower Silurian." About 20 years later, Jaggar[5] published another general discussion of these rocks and he placed the strata that are now known as the Deadwood formation in the Middle Cambrian. Jaggar did not use the term Deadwood as a formational name, but in discussing the Cambrian strata of the Black Hills he stated that the "type locality" is in Whitewood Canyon, just below Deadwood. Later in 1901, Darton[6] employed the name Deadwood as though Jaggar had

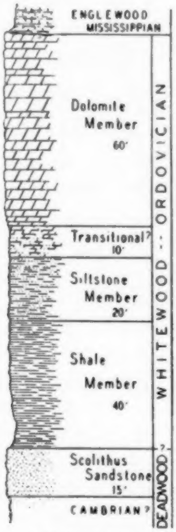

FIG. 1.—Section of Ordovician strata exposed just northeast of Deadwood, South Dakota.

defined and named the formation. In 1904 and in 1909, Darton[7] also correlated the Deadwood with the Middle Cambrian, and he then placed the Cambro-Ordovician (Deadwood-Whitewood) boundary above the gray shale, which immediately overlies the so-called Scoli-

[5] T. A. Jaggar, Jr., "The Laccoliths of the Black Hills," *U. S. Geol. Survey Ann. Rept. 21*, Pt 3 (1901), pp. 176–81.

[6] N. H. Darton, "Preliminary Description of the Geology and Water Resources of the Southern Half of the Black Hills and Adjoining Regions in South Dakota and Wyoming," *U. S. Geol. Survey Ann. Rept. 21*, Pt. 4 (1901), pp. 502–08.

[7] N. H. Darton, "Comparison of the Stratigraphy of the Black Hills, Bighorn Mountains, and Rocky Mountain Front Range," *Bull. Geol. Soc. America*, Vol. 15 (1904), pp. 382, 383, 434.
"Geology and Water Resources of the Northern Portion of the Black Hills and Adjoining Regions in South Dakota and Wyoming," *U. S. Geol. Survey Prof. Paper 65* (1909), pp. 12–20, 73–74.

thus sandstone, and below the siltstone (Fig. 1). Without presenting his reasons for doing so, Darton[8] later redefined this boundary so as to include the siltstone in the Deadwood formation; he believed this member to be only locally developed. Also, at this time (1925), Darton stated that the age of the Deadwood is Upper Cambrian, rather than Middle Cambrian, and since then it has been generally believed that the entire Deadwood belongs in the Upper Cambrian.

NEW EVIDENCE AND DEDUCTIONS

In the immediate vicinity of Deadwood[9] the writers obtained numerous fossils from the siltstone beds and a few from the underlying gray shale. Also, approximately 5 miles southeast of Deadwood, on Bear Butte Creek, the fossiliferous siltstone is separated from the typical buff Whitewood dolomite by about 8 feet of light-colored sandstone which yielded an abundant fauna. Most of the fossils obtained from the beds which lie between the Scolithus sandstone and the typical Whitewood dolomite are not very well preserved, but that they are Ordovician and not Cambrian in age is obvious. As no diagnostic fossils were obtained from the Scolithus sandstone or subjacent beds, the exact position of the Cambro-Ordovician boundary was not determined.

Below the Scolithus sandstone there are about 400 feet of conglomerate, sandstone, shale, limestone conglomerate, glauconitic sandstone, and sandy and dolomitic limestone. For the present at least, it is perhaps best to leave all of these beds in the Deadwood formation. Throughout the northern part of the Black Hills this formation does not vary greatly, but farther south it thins rapidly. Equivalent beds in central Wyoming, which are of somewhat greater thickness, are known by the same formational name, but farther west the beds that are presumably contemporaneous are known by different names. Certain of the faunal zones in the Upper Cambrian series of the upper Mississippi Valley have been recognized in the Deadwood formation.[10] The basal beds of the Deadwood lie unconformably on the eroded surface of pre-Cambrian metamorphic rocks; Middle and Lower Cambrian beds are believed not to be present. In the northern Black Hills the Deadwood is overlain by strata which con-

[8] N. H. Darton and Sidney Paige, "Central Black Hills, South Dakota," *U. S. Geol. Survey Atlas Folio 219* (1925), pp. 5–7, 24–25.

[9] In a road-cut on the east side of Whitewood Canyon, about 200 yards east of the intersection of South Dakota State Highway 24 and the Chicago and Northwestern Railroad.

[10] H. R. Meyerhoff and Christina Lochman, "Deadwood Faunas in South Dakota and Eastern Wyoming" (abstract), *Proc. Geol. Soc. America for 1935* (1936).

tain a Middle (?) Ordovician fauna. Between the beds which have yielded Upper Cambrian fossils and those which contain a Middle (?) Ordovician fauna there are strata which have yielded no diagnostic fossils. Although these are being retained tentatively as part of the Deadwood formation, their age is of course very uncertain.

The Scolithus sandstone, which was recognized as early as 1901 by Jaggar,[11] is a persistent and easily recognized unit in the northern Black Hills (and at Sheep Mountain, farther west). Good exposures of it are to be seen in the canyons of Whitewood, Spearfish, Two Bit, and Bear Butte creeks. Near Deadwood it consists of about 15 feet of light reddish brown, coarse-grained, quartzitic sandstone which is commonly cross-bedded and rarely ripple-marked and which contains many "worm-borings." Elsewhere in the northern Black Hills it is typically about 10–15 feet thick, but its basal part is exposed at only a few localities and in these it is difficult to "draw a line" between the Scolithus and the underlying beds. Near Deadwood, where the entire member is exposed in a fresh road-cut, quartzitic beds with "worm-borings" seem to grade into underlying sandy beds. On Little Elk Creek, approximately 15 miles southeast of Deadwood and near the southernmost extension of the Whitewood dolomite, the Scolithus sandstone is abnormally thick and is red in color. Over all of its area of outcrop, this member is overlain by a gray fissile shale which presents an abrupt change in lithologic character. The contact of these two members is quite distinct, but the lower part of the shale member contains many sand grains which were probably derived from the underlying sandstone. The upper surface of the Scolithus sandstone is irregular and is locally dark red in color; this color, as well as the silicification of the sandstone, may be, in part at least, the result of a period of exposure. No diagnostic fossils were found in the Scolithus and its age is therefore questionable. However, we are tentatively classing it with the Deadwood.

The gray fissile shale which immediately overlies the Scolithus sandstone is not very resistant to weathering and normally it is not well exposed. Several excellent exposures are available for study now, however, in road-cuts just north of Deadwood on South Dakota State Highway 24. Other exposures are to be seen on the east side of Whitewood Canyon near Whitewood Peak and in the canyons of Two Bit, Bear Butte, Spearfish, Little Spearfish, and Squaw creeks. Except in its basal portion, which contains a great deal of sand, this member is uniform in lithologic character, and it consists throughout of gray fissile shale which contains numerous small black phosphatic nodules

[11] T. A. Jaggar, Jr., *op. cit.*

and grains of quartz sand. At no locality was a complete exposure observed, but near Deadwood both the lower and the upper limits of this member can be determined and its thickness was calculated to be about 40 feet. This shale member is entirely absent in the southern portion of the Black Hills, but, according to Darton,[12] beds which apparently are equivalent to it occur in the Bear Lodge Mountains (including Sheep Mountain), west of the Black Hills. Macro-fossils are rare in this shale, but the writers obtained a few fragmentary fish scales, pelecypods, gastropods, and linguloid brachiopods and many micro-fossils—conodonts and scolecodonts. Almost all of the scolecodonts are strikingly similar to those that Stauffer[13] recently described from the Middle Ordovician of Minnesota, and they are either identical with, or very close to, the following species.

Arabellites brevidentatus Stauffer
Arabellites contritus Stauffer
Arabellites ignotus Stauffer
Arabellites tenuidentatus Stauffer
Arabellites tumidus Stauffer
Eunicites eximius Stauffer
Hyalinaecites plenus Stauffer
Lumbriconereites arcuatus Stauffer
Lumbriconereites cameratus Stauffer
Lumbriconereites cognitus Stauffer
Lumbriconereites speciosus Stauffer
Lumbriconereites webbi Stauffer
Nothrites gratus Stauffer
Oenonites dignus Stauffer
Oenonites inornatus Stauffer
Oenonites scelestus Stauffer
Protarabellites concavus Stauffer
Protarabellites delectus Stauffer
Protarabellites glenwoodensis Stauffer
Protarabellites intermedius Stauffer
Protarabellites productus Stauffer
Staurocephalites acutidentatus Stauffer
Thalenessites lobatus Stauffer

Fourteen of these 23 species of scolecodonts have been found previously in only the Spechts Ferry member of the Platteville formation; also, all of the genera in this list are represented in the Spechts Ferry and 4 of them (*Hyalinaecites*, *Nothrites*, *Staurocephalites*, and *Thalenessites*) have not been known to occur outside of it. Furthermore, the peculiar form (annelid ?) from the Spechts Ferry, which Stauffer described as *Rhabdochitinia? minnesotensis*, is present also in the shale member under consideration. As shown by Table I, the conodonts are similar to those that occur in the overlying siltstone, to those that Stauffer[14] has described from the Platteville (including the Glenwood and the Spechts Ferry) and Decorah formations (Middle

[12] N. H. Darton, "Sundance, Wyoming-South Dakota," *U. S. Geol. Survey Atlas Folio 127* (1905), p. 2.

[13] C. R. Stauffer, "Middle Ordovician Polychaeta from Minnesota," *Bull. Geol. Soc. America*, Vol. 44 (1933), pp. 1173–1218, Pls. 59–61.

[14] C. R. Stauffer, "Conodonts from the Decorah Shale," *Jour. Paleon.*, Vol. 4 (1930), pp. 121–28, Pl. 10.
"Decorah Shale Conodonts from Kansas," *ibid.*, Vol. 6 (1932), pp. 257–64, Pl. 40.
"Conodonts of the Glenwood Beds," *Bull. Geol. Soc. America*, Vol. 46 (1935), pp. 125–68, Pls. 9–12.
"The Conodont Fauna of the Decorah Shale (Ordovician)," *Jour. Paleon.*, Vol. 9 (1935), pp. 596–620, Pls. 71–75.

Ordovician) of the Upper Mississippi Valley, and to those that Branson and Mehl[15] have described from the Plattin limestone (Middle Ordovician) of Missouri and the Harding sandstone (Middle Ordovician) of Colorado.

TABLE I

CHART SHOWING KNOWN DISTRIBUTION OF CONODONTS FOUND IN SHALE AND SILTSTONE MEMBERS OF WHITEWOOD FORMATION OF NORTHERN BLACK HILLS

Conodont Genera and Species	*Whitewood Shale of Black Hills*	*Whitewood Siltstone of Black Hills*	*Platteville Formation of Minnesota*	*Decorah Formation of Minnesota*	*Plattin Limestone of Missouri*	*Harding Sandstone of Colorado*
ACONTIODUS Pander		x	x			
A. alveolaris Stauffer		x	x			
BELODUS Pander	x	x	x	x	x	
B. compressus Branson and Mehl	x				x	
B. sp.	x	x				
CHIROGNATHUS Branson and Mehl	x		x		x	x
C. delicatulus Stauffer	x		x			
CORDYLODUS Pander	x	x		x	x	x
C. concinnus Branson and Mehl		x			x	
C. plattinensis Branson and Mehl	x	x			x	
C.? primus Branson and Mehl	x	x				x
CYRTONIODUS Stauffer	x		x	x		
C. erectus Stauffer	x		x			
LEPODUS Branson and Mehl		x			x	x
Lepodus sp.		x				
MICROCOELODUS Branson and Mehl	x	x	x	x	x	
M. expansus Branson and Mehl	x	x	x			
OISTODUS Pander	x	x	x	x	x	
O. curvatus Branson and Mehl	x	x	x	x	x	
O. inclinatus Branson and Mehl	x	x	x	x	x	
O. suberectus Branson and Mehl	x	x	x	x	x	
OZARKODINA Branson and Mehl	x	x	x	x	x	
O. concinna Stauffer	x		x	x		
O. robusta Stauffer		x	x	x		
O. sp.	x					
PALTODUS Pander	x	x	x	x	x	
P. compressus Branson and Mehl	x	x	x		x	
P. elegans Stauffer	x	x	x	x		
P. gracilis Branson and Mehl	x	x			x	
PRIONIODUS Pander	?		?	?		
P.? sp.	x					
PTEROCONUS Branson and Mehl	x	x	x	x	x	
P. robustus Stauffer	x	x	x	x		
P. sp.	x					
P.? sp.	x					
TRICHOGNATHUS Branson and Mehl	x	x	x	x	x	x
T. barbarus Stauffer		x	x			
T. primus Branson and Mehl	x	x				x
T. recurvus Branson and Mehl	x	x	x	x	x	
T.? sp.	x	x				
Form α (Figs. 14–16 on Pl. 2)	x					
Form β (Fig. 4 on Pl. 1 and Fig. 2 on Pl. 2)	x					
Fish plates	x	x				x

As recognized by Darton,[16] the beds which immediately overlie the gray fissile shale and underlie the typical Whitewood dolomite, are quite distinct in lithologic character. In the vicinity of Deadwood these beds total about 30 feet in thickness. The lower two-thirds of them are composed of coarse-grained, light gray siltstone which, ex-

[15] E. B. Branson and M. G. Mehl, *op. cit.*, pp. 19–38, 101–19, Pls. 1, 2, 8–10.

[16] N. H. Darton, "Geology and Water Resources of the Northern Portion of the Black Hills and Adjoining Regions in South Dakota and Wyoming," *U. S. Geol. Survey Prof. Paper 65* (1909), p. 19.

cept for certain reddish calcareous lenses, is soft and friable. The upper portion of these beds becomes progressively less sandy and more dolomitic, and therefore appears to be gradational or transitional to the typical Whitewood dolomite (Fig. 1). The siltstone contains an abundant and varied fauna consisting of sponges, echinoderms, brachiopods, bryozoans, molluscs, trilobites, ostracodes, scolecodonts, conodonts, fish scales, *et cetera*, but with the exception of the conodonts the fossils are not well preserved. Sponges are represented by only small hexactinellid spicules. The echinoderm remains found are also not very significant since they consist of only columnals and a few isolated cystoid plates. Most of the brachiopods obtained are not well enough preserved to permit specific identification, but with the help of G. A. Cooper the writers have been able to ascertain that they represent the following genera: *Lingula*, *Crania?*, *Dalmanella?* [cf. "*D. hamburgensis* (Walcott)" of the Black River of Minnesota, not of the Pogonip of Nevada], *Sowerbyella*, *Rafinesquina*, *Strophomena*, *Rhynchotrema* [cf. *R. minnesotense* (Sardeson)], and *Zygospira*. Representatives of the bryozoan genus *Helopora* are very abundant, and one specimen that is probably referable to *Rhinidictya* was found. The writers also obtained a few internal molds of clams and gastropods, but they are poorly preserved and are difficult to identify; however, some of the gastropods probably represent the genus *Archinacella*. Also, collections of the writers contain one rather large crushed fragmentary cephalopod, which belongs in the genus *Endoceras*. Trilobites are not rare and, although fragmentary, they are relatively well preserved and merit considerable attention. Representatives of the subfamily *Pterygometopinae* are abundant; David M. Delo has written the writers that some of these are clearly referable to the genus *Calliops*. Also, a few specimens were obtained which probably represent the trilobite genera *Bathyurus*, *Isotelus*, and *Ceraurus*. Both smooth and ornate ostracodes are present, but their poor preservation prohibits their identification. Scolecodonts are abundant but as it is hardly possible to remove them intact from the matrix, their specific affinities can not be determined; representatives of the following genera were obtained: *Arabellites*, *Protarabellites*, and *Lumbriconereites*. In contrast to the rest of the fauna, the conodonts are well preserved and were obtained in considerable variety (Table I). These represent ten distinct genera and whereas, in general, they are very similar to those of the underlying shale, certain differences are recognizable. In the siltstone, *Paltodus* is rather rare; representatives of *Cordylodus* and *Trichognathus* are more abundant, exhibit more variety, and are more advanced than in the shale. Furthermore,

at Deadwood and in Spearfish Canyon there are two very abundant forms (fish remains ?) in the shale that are not congeneric with any of the siltstone specimens the writers have found (Fig. 4 on Pl. 1 and Figs. 14–16 on Pl. 2). The conodont faunas of the shale and siltstone members under consideration, taken together, are distinctly more advanced than those known from the Glenwood shale (basal Platteville) of Minnesota and the Harding sandstone of Colorado, but they are comparable and very similar to those of the upper parts of the Platteville formation (including the Spechts Ferry shale which formerly was included in the overlying Decorah formation) of Minnesota and the Plattin limestone of Missouri; not only is the general assemblage similar to those of the upper Platteville and the Plattin, but as shown in Table I several species are common to the three formations. Furthermore, the peculiar scolecodont genera *Paleonereites*, *Hyalinaecites*, *Nothrites*, and *Thalenessites* are, insofar as is now known, represented in only the shale member near Deadwood and in the Spechts Ferry. In the vicinity of Deadwood small fish plates are not rare in the siltstone and, although they are fragmentary, in general they seem to resemble those that occur in the Harding sandstone of Colorado and its equivalents in central Wyoming;[17] the

[17] C. D. Walcott, "Preliminary Notes on the Discovery of a Vertebrate Fauna in Silurian (Ordovician) Strata [Colorado]," *Bull. Geol. Soc. America*, Vol. 3 (1892), pp. 153–72, Pls. 3–5.
N. H. Darton, "Fish Remains in Ordovician Rocks in Bighorn Mountains, Wyo-

EXPLANATION OF PLATE 1

All specimens illustrated came from lower parts of Whitewood formation near Deadwood, South Dakota. Figures 2–4, 6, 8, and 10–12 are from shale member of that formation. Figures 1, 5, 7, 9, 13, 14, 17–21, 24, and 25 are from siltstone member. Figures 15, 16, 22, and 23 are from so-called transitional beds (text Fig. 1). Drawings were made by Dan Enich. Figured specimens are at State University of Iowa where they are numbered 1175–1195.

FIG. 1.—*Trichognathus* cf. *T. barbarus* Stauffer, ×45.
FIG. 2.—*Trichognathus* cf. *T. primus* Branson and Mehl, ×45.
FIG. 3.—*Paltodus gracilis* Branson and Mehl, ×45.
FIG. 4.—Form β (fish remains ?), ×45.
FIG. 5.—*Cordylodus plattinensis* Branson and Mehl, ×45.
FIG. 6.—*Cordylodus* cf. *C. concinnus* Branson and Mehl, ×45.
FIG. 7.—*Oistodus inclinatus* Branson and Mehl, ×20.
FIG. 8.—*Oistodus curvatus* Branson and Mehl, ×20.
FIG. 9.—*Oistodus suberectus* Branson and Mehl, ×20.
FIG. 10.—*Belodus compressus* Branson and Mehl?, ×45.
FIG. 11.—*Microcoelodus* cf. *M. expansus* Branson and Mehl, ×45.
FIG. 12.—*Chirognathus* cf. *C. delicatulus* Stauffer, ×45.
FIG. 13.—*Microcoelodus* cf. *M. expansus* Branson and Mehl, ×45.
FIG. 14.—*Ozarkodina* cf. *O. robusta* Stauffer, ×45.
FIGS. 15, 16.—*Bellerophon* cf. *B. similis* Ulrich and Scofield, ×1.
FIGS. 17–21.—*Calliops* sp., ×4. Figures 19–21 represent one specimen.
FIGS. 22, 23.—*Tripteroceras* sp., ×1.
FIG. 24.—*Rhynchotrema* cf. *R. minnesotense* (Sardeson), ×2.
FIG. 25.—*Dalmanella?* cf. "*D. hamburgensis* (Walcott)," ×2.

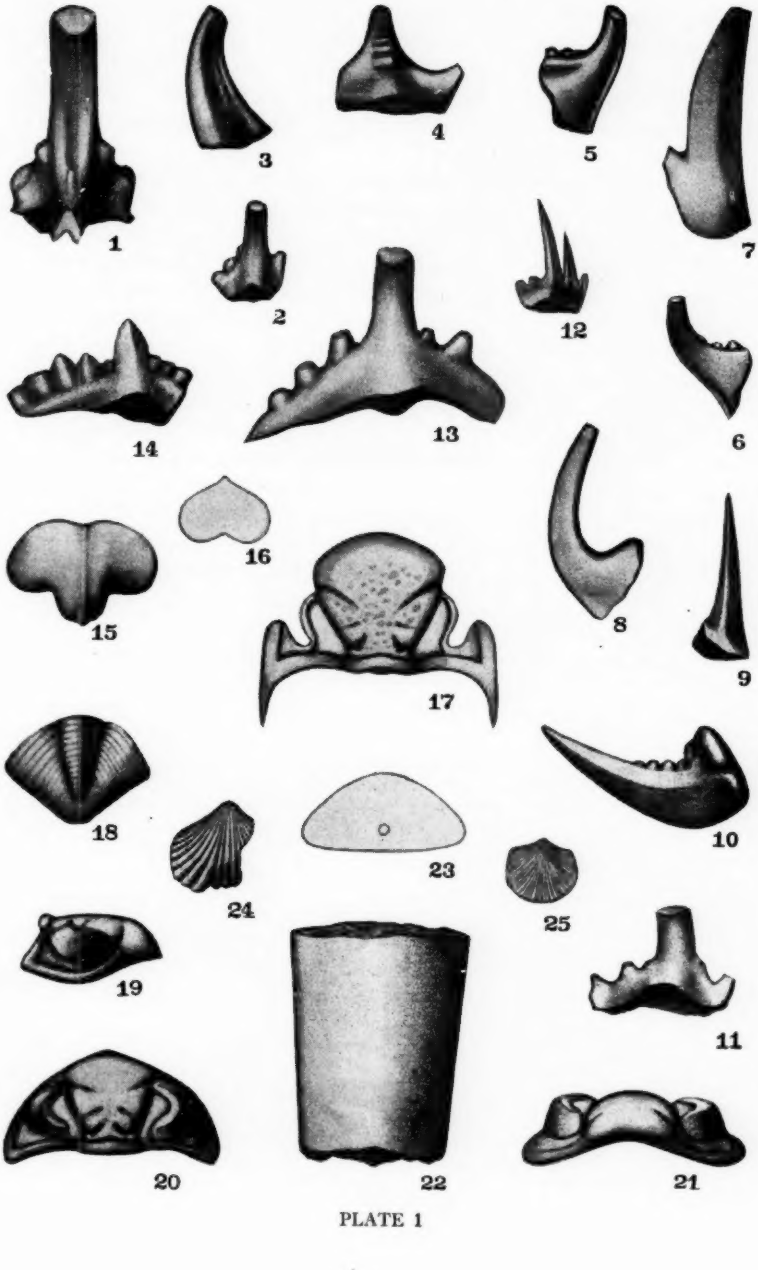

PLATE 1

fish plates which Darton[18] obtained from a loose boulder north of Nemo, South Dakota (about 16 miles southeast of Deadwood), probably came from this siltstone member because Nemo is slightly south of the southernmost extension of the typical Whitewood, and the lower parts of that formation presumably extend farther south than the dolomite part.

In most places in the northern Black Hills where the lower part of the Whitewood formation is exposed, there are about 8–10 feet of non-fossiliferous dolomitic sandstone or arenaceous dolomite above the siltstone member just discussed and below the Whitewood dolomite. Typically the lower part of these intermediate beds is very arenaceous, whereas the upper part is very dolomitic; therefore, they appear to be more or less transitional between the siltstone and the dolomite. However, in the canyon of Bear Butte Creek, near Galena, South Dakota, strata which occupy the same stratigraphic position as these transitional beds are about 20 feet thick and the upper half of them is composed of white non-dolomitic sandstone. About 1 foot from the top of this sandstone is a 6-inch bed which is abundantly fossiliferous. Most of the fossils obtained are pelecypods which ap-

ming, with a Résumé of Ordovician Geology of the Northwest," *ibid.*, Vol. 17 (1906), pp. 541–66, Pls. 73–79.

Edwin Kirk, "The Harding Sandstone of Colorado," *Amer. Jour. Sci.*, Ser. 5, Vol. 20 (1930), pp. 456–66.

[18] N. H. Darton, "Discovery of Fish Remains in Ordovician of the Black Hills, South Dakota" (abstract), *Bull. Geol. Soc. America*, Vol. 19 (1909), pp. 567–68.

EXPLANATION OF PLATE 2

All specimens illustrated came from lower parts of Whitewood formation in general vicinity of Deadwood, South Dakota. Figures 1, 8, and 18 came from siltstone member; others from shale member (text Fig. 1). Drawings were made by Dan Enich. Figured specimens are at State University of Iowa where they are numbered 1196–1215.

FIG. 1.—*Acontiodus* aff. *A. alveolaris* Stauffer, ×45.
FIG. 2.—Form β (fish remains ?), ×45.
FIG. 3.—*Trichognathus?* sp., ×45.
FIG. 4.—*Trichognathus?* sp., ×45.
FIG. 5.—*Paltodus compressus* Branson and Mehl, ×45.
FIG. 6.—*Pteroconus* sp., ×45.
FIG. 7.—*Ozarkodina?* sp., ×45.
FIG. 8.—*Cordylodus?* aff. *C.? primus* Branson and Mehl, ×45.
FIG. 9.—*Pteroconus?* sp., ×45.
FIG. 10.—*Ozarkodina concinna* Stauffer, ×45.
FIG. 11.—*Pteroconus* aff. *P. robustus* Stauffer, ×45.
FIG. 12.—*Cordylodus?* aff. *C.? primus* Branson and Mehl, ×45.
FIG. 13.—*Belodus compressus* Branson and Mehl?, ×45.
FIGS. 14–16.—Form α (fish remains ?), ×45.
FIG. 17.—*Oistodus curvatus* Branson and Mehl?, ×20.
FIG. 18.—*Oistodus curvatus* Branson and Mehl, ×20.
FIG. 19.—*Oistodus inclinatus* Branson and Mehl, ×20.
FIG. 20.—*Prioniodus?* sp., ×45.

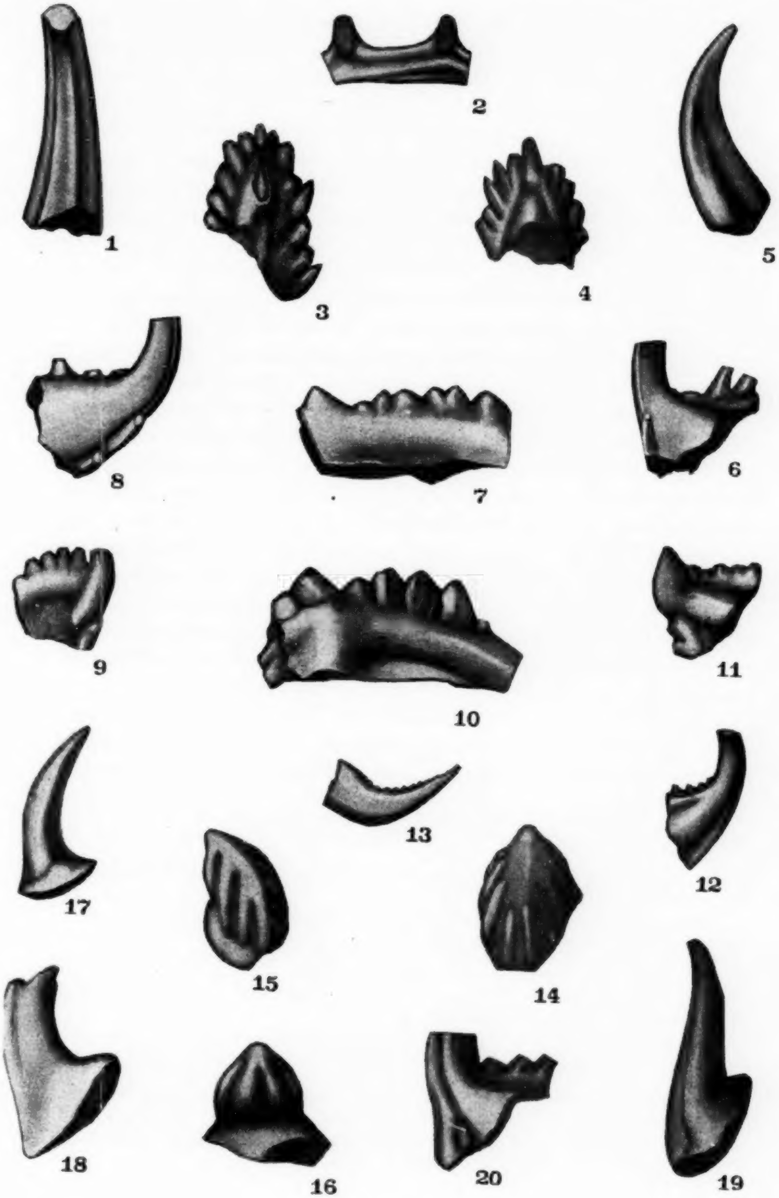

PLATE 2

parently represent only one species, *Cyrtodonta* cf. *C. gibbera* Ulrich. *Bellerophon* cf. *B. similis* Ulrich and Scofield is also fairly abundant and a few fragmentary remains of other gastropods were found. One brachiopod, *Rhynchotrema?* sp., and three conspecific cephalopods, *Tripteroceras* aff. *T. hastatum* (Billings), were collected. This sandstone bed also yielded a few fragmentary conodonts, some of which are referable to the long-ranging genus *Oistodus*. None of these fossils is particularly diagnostic, but the assemblage seems to indicate a Middle Ordovician age for the containing sandstone.

The typical Whitewood dolomite of the northern Black Hills is well exposed at the type locality in Whitewood Canyon, just north of Deadwood. There it consists of about 60 feet of massively bedded, mottled buff dolomite, the upper parts of which are locally cherty. Due to the resistance of the dolomite to erosion, this member is prominent topographically, and typically it crops out in the form of steep cliffs. At certain horizons it is abundantly fossiliferous, and some of the more characteristic forms are *Receptaculites arcticus* Etheridge?, *Streptelasma* sp., *Halysites gracilis* (Hall)?, *Maclurina* sp., and *Hormotoma* sp. A zone in the upper half of these dolomite beds has yielded a considerable cephalopod fauna consisting of representatives of the following genera: *Endoceras*, *Cyclendoceras*, *Ephippiorthoceras*, *Spyroceras*, *Wilsonoceras*, *Diestoceras*, *Cyrtogomphoceras*, and *Winnipegoceras*. Illustrations and detailed descriptions of these cephalopods will be published in a subsequent paper. The Bighorn dolomite of central and western Wyoming,[19] the Red River formation of Manitoba and equivalent beds south of Hudson Bay and in northern Canada,[20] the Cape Calhoun formation of northern Greenland,[21] the English Head and Vauréal formations of Anticosti Island,[22] and the Stewart-

[19] A. K. Miller, "The Cephalopods of the Bighorn Formation of the Wind River Mountains of Wyoming," *Trans. Connecticut Acad. Arts and Sci.*, Vol. 31 (1932), pp. 193–297, Pls. 1–31.
Aug. F. Foerste, "Bighorn and Related Cephalopods," *Denison Univ. Bull., Jour. Sci. Lab.*, Vol. 30 (1935), pp. 1–96, Pls. 1–22.

[20] Aug. F. Foerste, "The Cephalopods of the Red River Formation of Southern Manitoba," *ibid.*, Vol. 24 (1929), pp. 129–235, Pls. 11–39.
Aug. F. Foerste and T. E. Savage, "Ordovician and Silurian Cephalopods of the Hudson Bay Area," *ibid.*, Vol. 22 (1927), pp. 1–108, Pls. 1–24.
Aug. F. Foerste, "The Cephalopods of Putnam Highland," *Michigan Univ. Mus. Paleon. Contrib.*, Vol. 3 (1928), pp. 25–70, Pls. 1–11.

[21] Gustaf T. Troedsson, "On the Middle and Upper Ordovician Faunas of Northern Greenland, I, Cephalopods," *Meddelelser om Grønland*, Vol. 71 (1926), pp. 1–157, Pls. 1–65.
Curt Teichert, "Untersuchungen an actinoceroiden Cephalopoden aus Nordgrönland," *Meddelelser om Grønland*, Bd. 92, Nr. 10 (1934), pp. 1–47.

[22] Aug. F. Foerste, "The Cephalopod Fauna of Anticosti," *Canada Geol. Survey Mem. 154* (1927), pp. 257–321, Pls. 27–58.

ville dolomite of the upper Mississippi Valley[23] have yielded closely related cephalopod faunas, and presumably these formations are not greatly different in age from the Whitewood. Their place in the stratigraphic column is, at present, more or less of a moot question, but they almost certainly may be correlated with the Upper Ordovician. The typical Whitewood dolomite rests with apparent conformity on Mohawkian(?) strata, and it is overlain unconformably by the Mississippian Englewood formation; its stratigraphic position is, therefore, compatible with an Upper Ordovician age.

SUMMARY AND CONCLUSIONS

The data presented in the preceding paragraphs seem to indicate that all of the beds which occur in the northern Black Hills above the Scolithus sandstone and below the typical Whitewood dolomite may be correlated with the Middle Ordovician, and that they are not greatly different in age from the Platteville and Decorah formations of the upper Mississippi Valley, the Plattin limestone of Missouri, and the Harding sandstone of Colorado and its equivalents in central Wyoming. No diagnostic fossils were found in the Scolithus sandstone or the subjacent beds and therefore their age was not determined. The typical Whitewood dolomite presumably is Upper Ordovician in age. It seems advisable for the present at least to include all of the Ordovician beds above the Scolithus sandstone in the Whitewood formation.

[23] G. Marshall Kay, "Ordovician Stewartville-Dubuque Problems," *Jour. Geol.*, Vol. 43 (1935), pp. 561–90.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 20. NO. 10 (OCTOBER. 1936). PP. 1342-1356. 5 FIGS.

STRATIGRAPHY OF ARKANSAS-OKLAHOMA COAL BASIN[1]

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Washington, D. C.

ABSTRACT

The general stratigraphic results of detailed field investigations covering a large part of the Arkansas-Oklahoma coal basin are briefly summarized. Isopach maps of the Atoka, McAlester, Savanna, and Boggy formations show that the maximum thickness of the Atoka formation is somewhere southeast of the coal basin, that the thickest parts of the McAlester and Savanna formations lie a short distance north of the Choctaw fault, and that all of the formations thin westward and northward. There are unconformities at the base of the Hartshorne and Savanna sandstones. Much of the deposition was marine in the western part and continental or very shallow water in the eastern part of the coal basin. The source of the sediments is believed to be (1) Llanoria, (2) the previously deposited Stanley, Jackfork, and Atoka of the Ouachita Mountains, (3) the Arbuckle Mountains, and (4) an uplift of rocks resembling those of the Arbuckle Mountains which, in Pennsylvanian time, stood near the present location of Black Knob Ridge. Minor structural movements occurred within the coal basin during the time of deposition of the formations. The Atoka formation is of Pottsville age, and the Hartshorne, McAlester, Savanna, and Boggy formations are of Allegheny age.

INTRODUCTION

The Arkansas-Oklahoma coal basin is an east-west trending structural and depositional basin about 50 miles wide and 180 miles long, that lies south of the Ozark-Boston Mountain uplift and north of the Ouachita uplift (Fig. 1). On the east it ends near Russellville, Arkansas, beyond which place a structural rise has elevated the coal-bearing formations so high that, with the exception of a small outcrop on the crest of a hill near Conway, they have been removed by erosion. At the west end of the basin the coal-bearing formations pass beneath younger strata. Thus, the surface geology of the coal basin is that of a westward-plunging trough lying between two major uplifts.

Since 1930 the United States Geological Survey has conducted detailed investigations, chiefly by plane-table mapping, of the geology and mineral resources of more than half of the total area of the Arkansas-Oklahoma coal basin. In 1930, a field party working under the direction of T. A. Hendricks made investigations in the McAlester district, Oklahoma, and in 1931 that work was continued eastward through the Howe-Wilburton district to the Arkansas State line, and

[1] Published by permission of the director of the United States Geological Survey. Manuscript received, July 28, 1936.

[2] United States Geological Survey.

westward into the Lehigh district. In 1933, T. A. Hendricks and C. B. Read mapped the outcrop lines of the coal beds in the Lehigh district. In 1934, a party working under the direction of M. M. Knechtel completed the investigation of the geologic features of the Lehigh district, a party working under the direction of C. H. Dane studied the geologic features of the Quinton-Scipio district, Oklahoma, which lies adjacent to the north side of the McAlester district, and a party working under the direction of T. A. Hendricks studied the geologic features of the westernmost two-thirds of the Arkansas coal field. Much

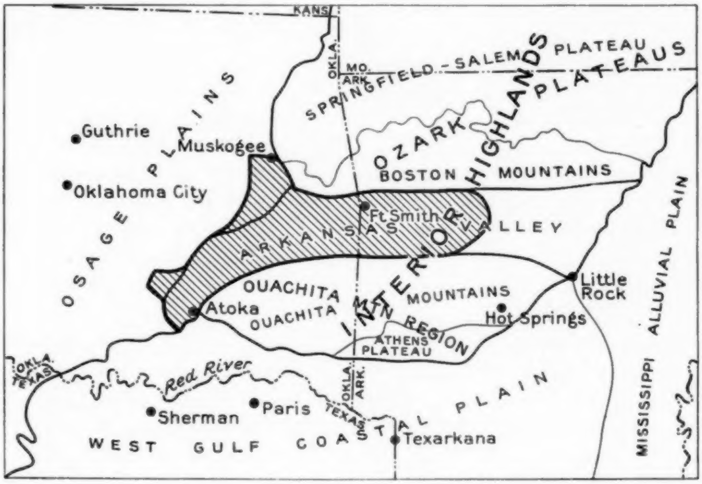

FIG. 1.—Outline map showing location of Arkansas-Oklahoma coal basin (shaded area) and its relation to physiographic provinces.

information on stratigraphy and sedimentation was obtained in the course of that work and most of it is as yet unpublished. This brief summary of the regional stratigraphic relations is based on that information, together with all available published data.

The strata which crop out within the coal basin are of Middle Pennsylvanian age and constitute a thick sequence of alternating sandstones and shales containing locally thin limestone beds and many coal beds, of which nine are sufficiently thick to have been mined commercially (Fig. 2). Most of these strata contain abundant plant material and probably are of continental or littoral origin. Some beds, particularly in the western and northwestern parts of the basin,

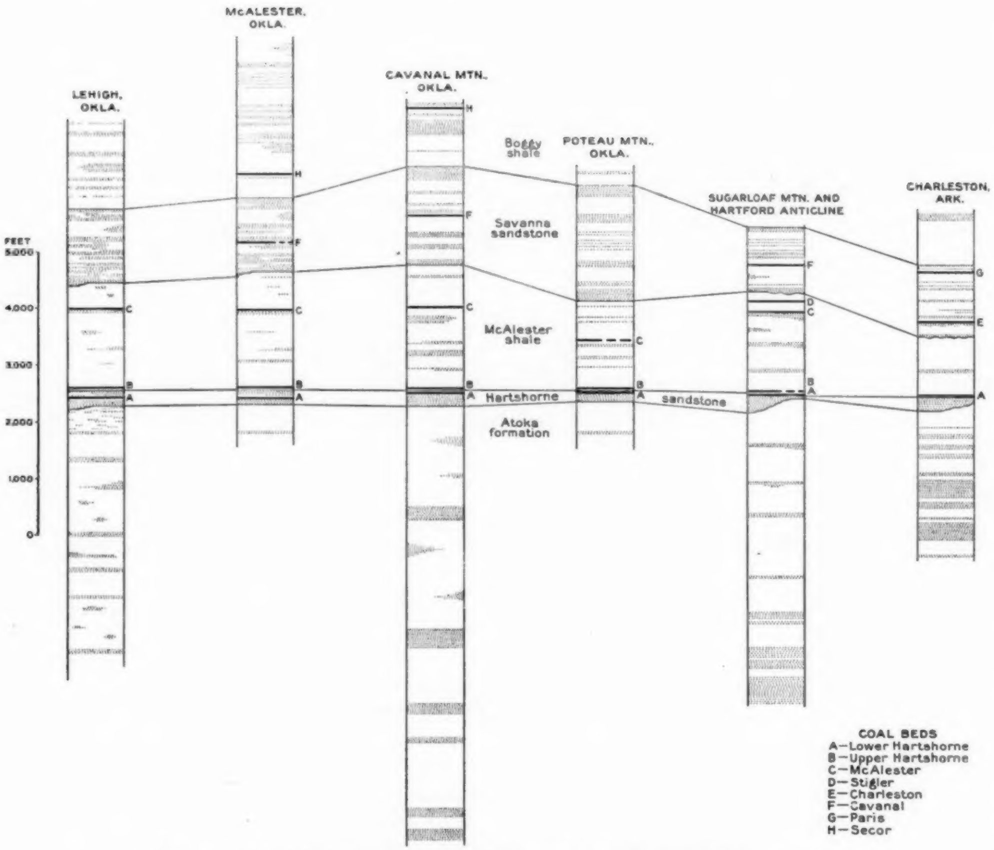

FIG. 21—Columnar sections of Pennsylvanian rocks of Arkansas-Oklahoma coal basin. Blank zones in sections represent shale.

contain abundant marine fossils. The formations of the coal basin are, from oldest to youngest, the Atoka formation, the Hartshorne sandstone, the McAlester shale, the Savanna sandstone, and the Boggy shale (Fig. 2).

ROCK FORMATIONS

Atoka formation.—The Atoka formation is generally considered the oldest formation of the Arkansas-Oklahoma coal basin. In the areas surrounding the coal basin it rests on several different formations. Throughout the Boston Mountains, north of the coal basin, and along the Arkansas River near Muskogee, it overlies rocks of the Morrow group unconformably.[3] Southwest of Coalgate, in the southwestern part of the coal basin, the Atoka rests on the Wapanucka limestone. On the north bank of North Boggy Creek between Atoka and Stringtown, in the extreme southern part of the coal basin, the Wapanucka limestone is absent and the Atoka formation rests unconformably on black shale of the Springer formation. On the crests of two anticlines in the Arkansas Valley in Arkansas and southeast of the coal basin the Atoka formation rests on Jackfork sandstone.[4] In the Ouachita Mountains, which lie south of the coal basin, the Atoka rests on the Johns Valley shale wherever that formation is present and on the Jackfork sandstone elsewhere.[5] The formations known to underlie the Atoka formation are all of Lower Pennsylvanian (Pottsville) age.[6] The base of the formation has also been encountered in many wells in the northern and western parts of the coal basin, and the writers know of no well in which the Atoka formation has been found to rest on beds of any age other than Pottsville.

The Atoka formation consists of alternating sandstone and shale. The formation is approximately 9,000 feet thick in the southeastern part of the Arkansas-Oklahoma coal basin and decreases progressively in thickness northwestward from there (Fig. 3). Throughout the greater part of the coal basin the formation thins northwestward

[3] A. H. Purdue and H. D. Miser, "Description of the Eureka Springs and Harrison Quadrangles," *U. S. Geol. Survey Atlas Folio 202* (1916), p. 16.

J. A. Taff, "Description of the Tahlequah Quadrangle," *U. S. Geol. Survey Atlas Folio 122* (1905), columnar section.

C. W. Wilson, Jr., "Age and Correlation of Pennsylvanian Surface Formations, and of Oil and Gas Sands of Muskogee County, Oklahoma," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 19, No. 4 (April, 1935), pp. 505–06.

[4] G. C. Branner, *Geologic Map of Arkansas*, Arkansas Geol. Survey (1929).

[5] H. D. Miser, "Carboniferous Rocks of Ouachita Mountains," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 18, No. 8 (August, 1934), p. 981.

[6] David White, "Age of Jackfork and Stanley Formations of Ouachita Geosyncline, Arkansas and Oklahoma, as Indicated by Plants," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 18, No. 8 (August, 1934), p. 1016.

by the thinning of each individual unit; this feature in the Muskogee-Porum district, Oklahoma, has been described by Wilson.[7] Between Coalgate and Ada in the extreme southwestern part of the Oklahoma coal field, however, Morgan[8] attributes the very rapid westward thinning of the Atoka formation to uplift and erosion of the formation prior to the deposition of the Hartshorne sandstone.

The Atoka formation is well exposed in the southern part of the Arkansas coal field, and in sections near Heavener and Atoka in the Oklahoma coal field. In Arkansas and near Heavener the formation consists of dark shales intercalated with 7–10 sandstone beds. The

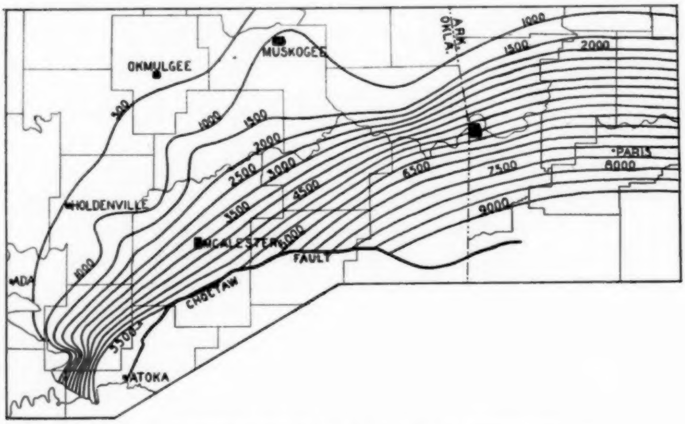

FIG. 3.—Isopach map of Atoka formation. Interval between isopach lines is 500 feet.

sandstones are very irregular in bedding; they are lenticular, fine to coarse-grained, and generally muddy. At many places the sandstone beds are channel deposits and vary greatly in thickness over short distances, but general sandy zones or groups of sandstone beds are fairly continuous over large areas. A careful study of surface exposures and available well logs shows that the general sandy zones in the formation are continuous north and south across the Arkansas coal field and vary little in total thickness. However, individual sandstone beds within the zones vary greatly and the shales between the sandy zones thin progressively from south to north.

[7] C. W. Wilson, Jr., *op. cit.*

[8] G. D. Morgan, "Geology of the Stonewall Quadrangle, Oklahoma," *Oklahoma Bur. Geol. Bull. 2* (1924), p. 64.

Near Atoka the formation consists of gray shales alternating with conglomeratic sandstone beds. A single phosphatic concretion of the type common in the Springer and Caney formations of the Arbuckle Mountains region was found in the conglomerate by H. D. Miser and T. A. Hendricks. West of Atoka the pebbles diminish in size and abundance and the conglomerates grade laterally into sandstones. At several localities in the central part of the Arkansas-Oklahoma coal basin the Atoka formation, which is several thousand feet thick in this area, consists of a sequence of alternating sandstone and shale. Marine invertebrates have been found in the Atoka formation at a a few localities and poorly preserved plant fossils are common in the formation. The formation extends eastward in Arkansas to the Mississippi alluvial plain, southward into the Ouachita Mountains, and northward into, and along the west end of, the Boston Mountains. The Atoka formation of the Boston Mountains constitutes the lower part of the Winslow formation (name now abandoned), in which Wilson[9] has recognized beds belonging to the Atoka, Hartshorne, McAlester, Savanna, and Boggy formations. The northward extension of the Atoka formation along the west end of the Boston Mountains constitutes the lower part of the Cherokee shale.[10]

Hartshorne sandstone.—The Hartshorne sandstone overlies the Atoka formation with an irregular contact. It ranges in thickness from 10 to 300 feet. Locally it consists of a single sandstone bed, but in other places it is composed of several sandstones separated by shale partings a few feet thick.

In the type area in Oklahoma, the Hartshorne sandstone includes the lower Hartshorne coal,[11] but in Arkansas the top of the Hartshorne sandstone lies 1–60 feet below the lower Hartshorne coal. This is due to the fact that the sandstone which lies between the lower and the upper Hartshorne coal in Oklahoma is represented in Arkansas only in the extreme southwestern part of the coal field where there are a few lenticular beds. The formation as defined in each state constitutes a mappable lithologic unit and the definitions accord with both current and past usage.

Near Atoka in the southern part of the Oklahoma coal field, the sandstones of the Hartshorne pass laterally into chert conglomerates containing pebbles as large as one inch in diameter. The size and

[9] C. W. Wilson, Jr., *op. cit.*, pp. 511–12.

[10] *Ibid.*, p. 513.

[11] T. A. Hendricks and C. B. Read, "Correlation of Pennsylvanian Strata in the Arkansas and Oklahoma Coal Field," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 18, No. 8 (August, 1934), p. 1052.

abundance of the pebbles decrease progressively northward and westward from Atoka.

The Hartshorne sandstone changes from 10 feet of shaly sandstone to 300 feet of massive to very irregularly bedded pure, coarse-grained sandstone within distances of 3–10 miles. The sandstone on fresh exposures has a distinctive ashy gray color. The textural characteristics and widespread blanket type of deposition, together with the fossil content of the formation indicate that it was deposited beneath an extensive body of water. Such parts of it as are thick and coarse-grained probably represent deposition in submarine channels cut in front of the mouths of streams flowing into the basin of deposition from the south. The thin, fine-grained and shaly parts of the formation probably were formed by littoral currents distributing and depositing the finer sediments in less agitated waters away from the stream mouths.

In the western part of the coal basin—west of Hartshorne, Oklahoma—the sandstone between the upper and lower Hartshorne coals is generally 10–20 feet thick, thin-bedded, fine-grained, and ripple-marked. About three miles east of Hartshorne, however, the sandstone is very soft, coarse-grained, massive, and pure, and reaches a thickness of 75 feet. Farther east the sandstone is absent at places for distances of a mile or more and the coal beds are separated by as little as two feet of sandy shale. Where the sandstone is present east of Wilburton, Oklahoma, it is generally coarse-grained and irregularly bedded, and appears to have been deposited in stream channels.

The lower Hartshorne coal extends over the entire area of the coal basin and marks the first period of stability of the basin at a level favorable for coal formation. Throughout the younger part of the geologic section this condition was repeated many times and the coal beds formed in such periods of stability supply the best horizon markers available in the sequence of rocks. In the eastern part of the basin, the roof of the lower Hartshorne coal contains abundant well preserved and diagnostic plant fossils together with a few brackish- or fresh-water invertebrates. In the Lehigh district, in the extreme western part of the basin, marine invertebrates are present in the roof shales. The presence of marine beds in the western part of the basin and continental or lacustrine deposits at the same horizon farther east has been demonstrated at many levels in the section above the lower Hartshorne coal. This suggests that at intervals the eastern shore of the Pennsylvanian sea extended roughly north and south along the western part of the basin in post-lower Hartshorne time, and that the major part of the Arkansas-Oklahoma coal basin was a lowland ex-

tending eastward from that sea and receiving sediments under fluviatile or lacustrine conditions.

McAlester shale.—The McAlester shale overlies the Hartshorne sandstone conformably and consists mostly of shale with several sandstones in the middle part and a number of coal beds in the upper part. An isopach map of the McAlester shale based on abundant data indicates that the greatest deposition during McAlester time took place a short distance north of the Choctaw fault (Fig. 4). The few sections that lie south of the axis of the basin are extremely thin, and this, together with the shore line character of the Hartshorne sand-

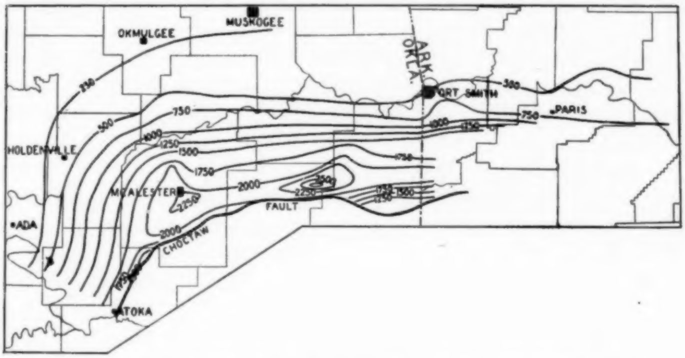

FIG. 4.—Isopach map of the McAlester shale. Interval between isopach lines is 250 feet.

stone in the same belt, indicates that the area of deposition of those two formations extended only a short distance south of the present location of the Choctaw fault. In the western part of the coal basin the McAlester shale thins westward by overlap[12] of the upper part of the formation. It also thins northward in both Oklahoma and Arkansas, but that thinning is for the most part accomplished by the thinning of each individual unit in the formation.

Throughout the part of the basin in which the formation is thickest it consists of three major divisions of about the same thickness. The lower unit is dark gray, platy shale, which contains sideritic concretions and which is clayey in the western part and sandy in the eastern part of its area of occurrence. The middle unit consists of alternating sandstone and shale. Most of the sandstones are fine-grained, ripple-marked, thin-bedded, and buff-colored; most of the shales are gray and sandy. Near Atoka, in the southern part of the coal basin,

[12] G. D. Morgan, *op. cit.*

the sandstones change to chert conglomerates. The upper unit consists chiefly of shale and extends from the top of the sandstone-bearing middle part to the base of the overlying Savanna sandstone. The McAlester coal is generally 2–10 feet above the base of the upper unit, but locally as much as 100 feet of shale is present between it and the underlying sandstone. The part of the McAlester shale between the McAlester coal and the base of the Savanna sandstone is made up largely of alternating continental and marine shales in which five or more thin coal beds are present. Throughout the southern part of the basin a group of two or three thin coals lies about 350–500 feet above the McAlester coal. One and locally two thin coals lie 100–150 feet above the McAlester coal, and one thin bed (the Stigler coal of the northern part of the basin) lies about 30–60 feet above the McAlester. This sequence of thin coal beds above the McAlester coal is particularly useful in identifying that interval in diamond drill records. Marine fossils are very abundant in shale and lenticular limestones in the upper part of the McAlester shale in the western part of the coal basin. In the extreme eastern part of Oklahoma and in Arkansas, however, marine fossils are absent in that part of the formation and the shales are much more sandy and micaceous.

At a few places in eastern Oklahoma and in Arkansas, theMcAlester shale continues northward into the Boston Mountains where it has previously been mapped as a part of the Winslow formation. North of the west side of the coal basin, however, the McAlester shale passes into the middle part of the Cherokee shale.[13]

Savanna sandstone.—The Savanna sandstone overlies the McAlester shale unconformably. The unconformity is most clearly shown on the northwest side of Sugarloaf Mountain in extreme eastern Oklahoma, where the basal sandstone of the Savanna cuts downward across about 100 feet of shale and truncates a sandstone bed in the upper part of the McAlester shale.

Numerous sections of the Savanna sandstone are available for study both from surface exposures and drill records. The Savanna sandstone has a maximum thickness of about 1,750 feet and is present in two localities both of which lie a short distance north of the Choctaw fault (Fig. 5). Few available data show that the formation thins southward from this area toward the Ouachita Mountains; abundant data show that the formation thins westward and northward. The northward thinning is accomplished largely by the thinning of each unit,[14] and the westward thinning is accomplished by both the

[13] C. W. Wilson, Jr., *op. cit.*, p. 513.

[14] C. W. Wilson, Jr., *op. cit.*

thinning of individual units[15] and overlap.[16] The Savanna sandstone is abnormally thin in a belt extending southeastward from Holdenville. The underlying McAlester shale maintains a uniform thickness across this belt, which leads to the conclusion that during Savanna time an uplift occurred in this region and resulted in the deposition of an abnormally thin section of Savanna sandstone. The presence of a similar zone of reduced thickness in the Boggy shale indicates that the uplift was progressive and extended throughout both Savanna and Boggy time.

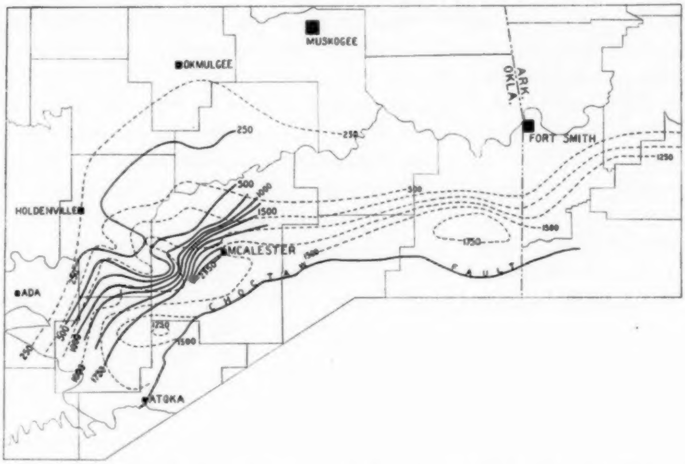

FIG. 5.—Isopach map of Savanna sandstone and Boggy shale. Interval between isopach lines is 250 feet. Isopach lines for Savanna sandstone are dashed and for Boggy shale are solid.

In the area of its maximum development the Savanna sandstone consists of alternating beds of sandstone and shale in which numerous thin coal beds are present. The sandstone beds are brown and highly variable both in grain size and bedding. The sandstone beds appear to have been deposited in stream channels, at least locally. False bedding that seems to be due either to initial foreset bedding, differential compaction, or a combination of those two processes is common and occurs on a large scale at numerous horizons. Near Atoka in the southern part of the region the sandstones grade laterally into chert

[15] J. A. Taff, "Coalgate, Indian Territory (Oklahoma)," *U. S. Geol. Survey Atlas Folio* 74 (1901), p. 3.

[16] G. D. Morgan, *op. cit.*, pp. 74 and 75.

conglomerates. Both marine and continental shales are present in the formation in all parts of the Arkansas-Oklahoma coal basin, but the marine shales are much more numerous in the western and northern parts of the area. In those two parts of the area the channel sandstones of the central part of the basin are absent and thin limestone beds that constitute convenient horizon markers are present in the Savanna sandstone.[17] Southwest of McAlester, Oklahoma, beds of red clay and variegated clay shales are present in the Savanna sandstone, but are absent throughout the remaining area of exposure of the formation.

The Cavanal, Charleston, and Paris coals are the thickest and most persistent coal beds in the Savanna sandstone, but numerous thin coals are present locally.

The Savanna sandstone extends eastward into Arkansas where its correlation with the formation in Oklahoma has been discussed by Hendricks and Read.[18] Since the publication of that discussion, additional areal mapping in the Arkansas coal field by Hendricks has shown that the top of the Savanna sandstone is only a short distance above the Paris coal or several hundred feet below the horizon indicated in the earlier publication.[18] The Savanna sandstone in Arkansas thus includes the upper part of the Fort Smith formation and the lower part of the Paris shale as defined by Collier.[19] North of the coal basin in Oklahoma, the Savanna sandstone is equivalent to beds in the Cherokee shale that lie a short distance below the Bluejacket sandstone member.[20]

Boggy shale.—The Boggy shale overlies the Savanna sandstone conformably throughout most of the area. In the Stonewall Quadrangle, Oklahoma, however, progressively younger beds of the Boggy shale overlap westward the older formations.[21] The greatest thickness of Boggy shale is 2,850 feet, about 12 miles southwest of McAlester (Fig. 5). The zone in which the thickness of the formation can be determined lies along the west side of the coal basin. Throughout that zone the formation thins progressively westward. The thinning probably is accomplished both by the thinning of each individual unit and by overlap. The Boggy shale consists of alternating shale and sand-

[17] G. D. Morgan, *op. cit.*, pp. 74 and 75.
Shepard W. Lowman, "Cherokee Structural History in Oklahoma," *Tulsa Geol. Soc. Digest* (1933).
C. W. Wilson, Jr., *op. cit.*, p. 504.

[18] T. A. Hendricks and C. B. Read, *op. cit.*, pp. 1050–58.

[19] A. J. Collier, *op. cit.*, pp. 18–21.

[20] C. H. Dane and T. A. Hendricks, "Correlation of the Bluejacket Sandstone, Oklahoma," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 20, No. 3 (1936), pp. 312–14.

[21] G. D. Morgan, *op. cit.*, p. 78.

stone. The lower Witteville and several very thin coal beds are present in the lower part of the formation locally, and the Secor (upper Witteville) coal is present over a rather large area. The shale of the formation is mostly dark gray and platy, although southwestward from McAlester blocky red clays and clay shales are common and increase in abundance toward the Arbuckle Mountains. Most of the sandstones are very irregular in bedding, grain size, and thickness. False bedding is common in the sandstone beds, and many of the sandstones appear to be flood-plain deposits in which stream-channel deposits are present locally. In the Stonewall Quadrangle, Oklahoma,[22] a limestone bed that is essentially a coral (*Campophyllum torquium*) reef is present in the upper part of the formation. In the Muskogee district[23] the Inola limestone member is present a short distance above the Secor coal in the lower part of the formation. Throughout the remainder of the area there are a few very local occurrences of impure limestone.

Both plant and invertebrate fossils are present in the Boggy shale. The invertebrate fossils are more abundant toward the west, and the plant fossils are most common in the lower 500 feet and upper 50 feet in the eastern part of the coal basin.

The basal part of the Boggy shale continues from Oklahoma eastward into Arkansas[24] where it includes a part of the Paris shale and all of the Savanna sandstone as those formations were described by Collier.[25] North of the Arkansas Valley the Boggy shale constitutes the middle part of the Cherokee shale. The Bluejacket sandstone member of the Cherokee shale is equivalent to the lowest mappable sandstone in the Boggy shale.[26]

SOURCE OF SEDIMENTS

The source of the sediments that formed the strata of the Arkansas-Oklahoma coal basin lies mainly farther south. Much of the material probably came directly from Llanoria,[27] an ancient land mass south of the present Ouachita Mountains, but probably a greater amount of material was supplied to the Hartshorne, McAlester, Savanna, and Boggy formations by the erosion of the Stanley, Jack-

[22] G. D. Morgan, *op. cit.*, p. 78.

[23] S. W. Lowman, "Lower and Middle Pennsylvanian Stratigraphy of Oklahoma East of the Meridian and North of the Arbuckle Mountains," *Tulsa Geol. Soc. Summaries and Abstracts of Technical Papers* (1932).
C. W. Wilson, Jr., *op. cit.*, pp. 504–11.

[24] T. A. Hendricks and C. B. Read, *op. cit.*, p. 1054.

[25] A. J. Collier, *op. cit.*, pp. 20–22.

[26] C. H. Dane and T. A. Hendricks, *op. cit.*

[27] H. D. Miser, "Llanoria, the Paleozoic Land Area in Louisiana and Eastern Texas," *Amer. Jour. Sci.*, 5th ser., Vol. 2 (1921), pp. 61–89.

fork, and Atoka formations of the Ouachita Mountains. Taff[28] has described chert conglomerates in the Atoka, Hartshorne, McAlester, Savanna, and Boggy formations along the southeast side of the Lehigh syncline near Atoka. Taff believed the chert of those conglomerates to have been derived from rocks of Ordovician-Devonian age now exposed in Black Knob Ridge, which lies at the west side of the Ouachita Mountains and only a few miles southeast of the present exposures of the conglomerates. It is obvious from the northwestward disappearance of the conglomerates that the sediments came from the southeast. The presence of the previously mentioned phosphatic concretion from the Springer formation or the Caney shale as a pebble in a conglomerate in the lower part of the Atoka formation near Atoka together with the eastward overlap of the Atoka formation onto the Springer formation near Stringtown indicates that an uplift of strata of the facies characteristic of the Arbuckle Mountains lay east of that part of the coal basin in Atoka time. It seems probable that the pebbles in the conglomerates of the coal-basin formations were derived from the rocks exposed in that uplift rather than from the strata now exposed in Black Knob Ridge, which belong to the facies characteristic of the Ouachita Mountains and contain no strata similar to the Caney shale or the Springer formation. Since the time of coal-basin deposition, however, northwestward overthrusting along the Choctaw fault has in part removed and in part concealed the rocks then exposed in the uplift, so that only the small outcrop of the Springer formation previously mentioned and a small amount of the underlying Caney shale are now exposed at that locality.

Morgan[29] describes coarse conglomerates in the McAlester, Savanna, and Boggy formations in the western part of the Stonewall Quadrangle, but does not mention their presence in the older formations. The Hartshorne sandstone has been overlapped by the McAlester shale in the part of the area where the conglomerates are found, and it is Morgan's[30] opinion that the Atoka was uplifted, folded, and peneplaned before the deposition of the Hartshorne sandstone. The existing data seem to indicate that uplift began in the Arbuckle Mountains in pre-Hartshorne time and continued throughout the deposition of the remaining coal-basin formations. Thus, the Arbuckle Mountains supplied some sediment to at least the southwestern part of the area of deposition of the coal-basin formations.

[28] J. A. Taff, "Atoka, Indian Territory (Oklahoma)," *U. S. Geol. Survey Atlas Folio 79* (1902), p. 5.

[29] G. D. Morgan, *op. cit.*, pp. 67–84.

[30] *Ibid.*, p. 64.

STRUCTURAL MOVEMENTS DURING DEPOSITION

There is considerable evidence of structural movements within the Arkansas-Oklahoma coal basin during the time of deposition of the various formations present. The previously cited overlaps in the southwestern part of the coal basin, to which Morgan has called attention, indicate that uplift within the Arbuckle Mountains region extended outward into at least a part of the coal basin at several times beginning in Atoka and extending into Boggy. The southward regional thickening of the strata, together with the fact that there is an alternation of marine and continental strata in the parts of the basin where the sediments are thickest, indicates that the basin was warped downward progressively during the time of deposition. According to Wilson[31] strata in the Atoka and overlying formations are thinner over the crests of monoclinal folds in the Muskogee-Porum district than in the adjacent synclines. There is no structural closure shown by the rocks exposed at the surface in the Poteau-Gilmore gas field in eastern Oklahoma, but the gas-bearing sand (Hartshorne sandstone), less than 2,000 feet below the surface, has a structural closure of 200 feet. On the Backbone and Hartford anticlines in western Arkansas, sandstone beds in the Atoka, Hartshorne, and McAlester formations locally contain plates of shale, several inches square, that are inclined at various angles to the bedding of the sandstone. The platy character of the shale indicates that it was lithified before deposition in the enclosing sandstone. The shale at each locality is identical in character with the shale that normally underlies the sandstone, and since large plates of shale can not be transported far before disintegrating, it is probable that the plates of shale found in the sandstone beds were derived from some near-by source. All such occurrences noted in the course of field work were in sandstones situated on the flanks of large anticlines, and it seems probable that the previously deposited beds of shale in the central part of the anticline were uplifted and subjected to erosion at the time of deposition of the shale-bearing sandstone beds. The previously-cited truncation of beds in the upper part of the McAlester shale by the Savanna sandstone indicates that some differential uplift followed by at least local erosion preceded the deposition of the Savanna sandstone. From a study of logs of wells in the Quinton gas field, Dane, Rothrock, and Williams[32] have concluded that a fault has dropped the Harts-

[31] C. W. Wilson, Jr., "Geology of the Muskogee-Porum District, Oklahoma," *Bull. Oklahoma Geol. Survey* (in preparation).

[32] C. H. Dane, H. E. Rothrock, and J. S. Williams, "Geology and Fuel Resources of the Quinton-Scipio District, Oklahoma," *U. S. Geol. Survey* (manuscript in preparation).

horne sandstone, in the Quinton gas field, more than 100 feet, but has had no effect on the lowest sandstone bed of the McAlester shale, which lies at the base of the middle part of the formation.

From the foregoing evidence, it is apparent that minor structural movements occurred at many places in the Arkansas-Oklahoma coal basin throughout the period of deposition of the strata now found there, but it is unlikely that any single structural movement affected the entire coal basin, and it is even doubtful that the unconformities at the base of the Hartshorne and Savanna sandstones extend over the entire area where these formations are present.

AGE OF ROCKS

Concerning the age of the formations of the Arkansas-Oklahoma coal basin, Read[33] states, on the evidence of plant fossils, that the Hartshorne, McAlester, Savanna, and Boggy formations are all of basal Allegheny age. He states further that

> this is exactly the conclusion arrived at by White,[34] but since then the tendency [by invertebrate paleontologists] has been to place the Hartshorne and even the McAlester in the upper Pottsville. As the purpose of this paper is not one of interregional correlation, and as this problem will be more fully treated in a subsequent publication, it is only necessary here to point out that while many species [of plants] which occur in the Hartshorne and McAlester (as well as in the Savanna and Boggy) occur in the upper Pottsville, as the line is now drawn in such areas as West Virginia, Ohio, and Illinois, few if any of these fail to pass upward into indisputable Allegheny. On the other hand, the Hartshorne and succeeding formations carry species which are not known below the base of the Allegheny (*Neuropteris capitate*, *Pseudopecopteris macilenta*, *Neuropteris desorii*, *et cetera*). To draw the division line at the base of the McAlester shale would be unfortunate, as the upper Hartshorne coal, by definition, is included in that unit and the roof of that coal carries a flora not easily separated from the flora of the Hartshorne formation. The flora of the McAlester coal is related closely to that of the Savanna and lower Boggy as well as to the Hartshorne. The obvious conclusion concerning these strata is that whatever may be their age it is undesirable to draw a major boundary within the sequence if this can be avoided. Available information favors a basal Allegheny (Clarion) age for the entire sequence [Hartshorne, McAlester, Savanna, and Boggy formations] here discussed, and the Pottsville-Allegheny division line should perhaps be drawn no higher than the top of the Atoka.

[33] T. A. Hendricks and C. B. Read, *op. cit.*, pp. 1055–56.

[34] J. A. Taff, David White, and G. H. Girty, "Geology of the McAlester-Lehigh Coal Field, Indian Territory," *U. S. Geol. Survey 19th Ann. Rept.*, Pt. 3 (1899), pp. 457–539.
A. J. Collier, David White, and G. H. Girty, "The Arkansas Coal Field," *U. S. Geol. Survey Bull. 326* (1907), pp. 24–31.

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EVIDENCE OF RECENT MOVEMENTS ALONG FAULTS OF BALCONES SYSTEM IN CENTRAL TEXAS[1]

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ABSTRACT

The so-called Balcones fault system of central and eastern Texas is an interesting regional phenomenon. It is peculiar in that it is more a system of grabens than a fault system proper. There is reason to believe that it is the surface expression of a comparatively recent, deep-seated, uplifting movement. Archeological finds suggest that there has been considerable movement in certain sections within the last 3,000–5,000 years. There is some evidence which suggests that the uplifting movement is still actively alive. It is believed that the faults of this system have not been a constructive cause of the accumulation of oil into the pools they border. Rather, it is believed that the faults have been destructive.

The so-called "Balcones fault system" or "fault zone" is a zone which is broken by more or less connected and interlocking parallel series of downfaulted blocks or grabens. It could be better called the Balcones fault-graben system. However, even this term would be misleading. These peculiar and very similar fault grabens break off against an almost straight line extending more than 250 miles along the west edge of the "zone." The line strikes through the cities of San Antonio, Austin, and Waco. There is no such definite eastern bordering belt. Fault grabens of the Balcones type are present as far southeast as the Orange pool, Orange County, Texas. They are common occurrences southwest of the Sabine uplift, particularly in Rusk, Cherokee, and Anderson counties, Texas.

The grabens are peculiar more to a region than to a narrow belt or zone. This region includes all of Texas east of the already described line, and its extensions northeast from Waco and southwest from San Antonio, and large parts of Louisiana and southern Arkansas.

The grabens vary in length from less than 0.5 mile to more than 30 miles, in width from a few feet to more than 4 miles, and in vertical displacement from only a few feet to more than 1,000 feet. The general strike of the grabens is parallel with the strike of the surface beds.

Where the width is more than a mile, in all grabens studied in

[1] Manuscript received, June 20, 1936.

[2] President, Central Texas Archeological Society. Acknowledgment is due E. A. Wendlandt, of the Humble Oil and Refining Company, for a frank criticism of the manuscript and many valuable suggestions and corrections.

close detail, they are not simple grabens, but rather compound—that is, grabens-within-grabens. A compound graben easy to see from mapping the surface beds is that opposite and just west of the south-central part of the Mexia pool, Limestone County, Texas.

FIG. 1.—Small fault over low anticlinal arch on White Rock Creek, McLennan County, Texas. Formation is Austin chalk. Fault has 2.5-foot throw at top and is completely absorbed in stratum level with boy's waist. Upper portion of fault fissure is filled with crystallized calcite veins, more than an inch thick and beautifully slickensided.

The smallest graben studied is an interior one which lies near the center of a large graben, approximately 300 feet deep, 0.75 mile wide,

and 30 miles long, extending north from Waco, McLennan County, Texas. This little graben is over the crest of a small anticline having about 3 feet of closure. It is in a chalk bluff about a mile above where the Waco-Gholson road crosses White Rock Creek, McLennan County. At the top of the bluff, where the graben is 40 feet across, there is 2.5 feet of vertical displacement. At 22 feet below the surface, the parabolically curved fault planes swing in toward each other and disappear in a soft stratum 2 feet thick, so that the two faults appear to form a large U.

All of the grabens mapped in close detail are terminated at their ends by the fault which is up-dip relatively to the regional inclination of the strata (generally the fault on the west side of the graben) turning sharply (generally toward the east) and diagonally across the graben, and ending against the down-dip (generally east side) fault, which is downthrown toward the west. Two easily mapped examples are: (1) where the Big Hill fault of Limestone County ends on the east at the north end of the Groesbeck gas field; (2) where the fault which strikes through the town of West, McLennan County, and swings east across the B. B. B. & C. Ry. Survey of Hill and McLennan counties at the northeast corner of the latter.

Until the present time, petroleum geologists have been interested only in the east-bordering or down-dip faults of these grabens, where oil has been found accumulated in "highs" lying east of, and alongside, the faults. These down-dip faults have been carefully studied, but little time and effort have been spent locating and measuring the throw of those forming the up-dip (generally western) sides of the grabens, in which the downthrow is on the side in the direction of regional dip. They are generally assumed to be of no importance in petroleum accumulation, although some shallow oil has been found within a graben in Navarro County, and some gas against, and on the high side of, the Big Hill fault in southern Limestone County, which is downthrown toward the east.

In general, it can be said that these peculiar grabens are found in that part of Texas, Louisiana, and Arkansas where there is a thickness of more than 2,000 feet of comparatively soft Cretaceous and younger formations which, in general, have a gentle east to southeast and, in extreme northeast Texas, south, and mostly homoclinal dip, nowhere in excess of 5° from the horizontal.

As to age, since Tertiary beds are faulted at the surface, it is generally assumed that the bulk of the faulting has taken place in post-Tertiary time. It is also generally assumed that these present surface expressions follow "old lines of weakness" and that there is more fault-

ing in the Cretaceous than in the Tertiary. Well-log data tend to support this last assumption, but it really antedates the interpretations made and may have influenced them. The theory of increased displacement on the faults at greater depth has not been proved or disproved as yet.

If one assumes, first, that the oil in such "fault-line" pools as Powell and Mexia was accumulated on anticlinal "highs" of the type of Garber or Cushing, before the faulting began, then, with the same data, it can be proved that the faulting does not increase with depth, but tends, instead, to disappear with depth.

This interpretation seems to be based on the most logical assumption. The local anticlinal "high" has been proved in practice to be the most common type of structural deformation governing the accumulation of oil in commercial pools. It is generally understood to be better practice to fit a hitherto unknown factor into a known picture, if this can be done, than it is to build a whole new picture containing new and untried interpretations. The assumptions that faults commonly follow old lines of weakness—disproved in the case of the prominent fault at the east side of the Oklahoma City field—and that they generally increase in amount of throw with depth, seem to the writer to be not only dangerous, but also nowhere supported by an indisputable interpretation of known conditions.

It seems better and more logical to assume that faults such as those under discussion are relatively a superficial structural phenomenon, not extending to great depths. Under a thick cover, rocks tend to yield to pressure by folding and flowing, rather than by faulting. The Ordovician beds in the Oklahoma City structure were probably at or near the surface when they faulted on the western side. When the next movement took place, not only the Ordovician, but also the overlying Pennsylvanian and Permian beds were probably so burdened with the weight of younger strata that they yielded to pressure by folding, thus causing the unfaulted anticline in the Permian beds now at the surface.

With these assumptions as a working hypothesis, the grabens of the so-called "Balcones system" are subject to a new, interesting, and probably important interpretation. This interpretation of the nature and particularly the age of the Balcones faulting depends partly on archeological studies which the writer has carried on for years in connection with his geological field work. It is believed that there is excellent evidence of very recent movements along all faults of the Balcones system which he has studied in close detail, that, at least in one locality, as much as 32 feet of faulting can be shown to have taken

place within possibly the last 4,000 years, and that in another place there has been a sudden displacement of about 20 feet some time within the last 2,500 years. He also believes that a proper combination of archeological and geological research will make it possible to fix the dates of several violent earthquakes, which accompanied faulting in the Balcones system, to within 500-year periods.

The archeological remains which have suggested recent faulting are called, for want of a better name, "buried middens." They are masses of midden material, including bone fragments, charcoal, and ashes, which are buried beneath stratified silts and other alluvial material.

These buried middens proper are not to be confused with the masses of buried midden material common to all streams in the southwest and elsewhere, discussed in detail in a paper by this writer.[3] The latter are the remains of middens which have been undercut by streams. The heavy material was dumped on a near-by shoal and there covered by advancing alluvium. It has been re-exposed at a lower level by the stream swinging back across the bottom. In them there are no bones, ashes, charcoal, or other light material. It has all been removed by the running water. There is also no evidence of unconformities connected with them.

The buried middens proper are those buried intact, undisturbed by running water, with all the light material such as charcoal and ash in place, just as when last occupied. These are separated from the overlying material by definite, clean-cut unconformable contacts.

Four such buried middens have been found near, and on the downthrown side of, some of the faults of the Balcones system.

The first of these middens was discovered by the late S. P. Simmons, professor of English at Baylor University. It is exposed in a drainage ditch cut across the bottom of Cow Bayou where the S.A.A.P. Railway crosses this stream about 3 miles south of Satin, Falls County, Texas. It consists of a thin layer of charcoal, ashes, flint flakes, and other artifacts, with numerous buffalo skulls, and extends approximately 200 yards along the canal at a depth of 16 feet below the level of the bottom proper. It also extends unbroken under the old bed of the stream which flowed at a depth of only 11 feet below the level of the bottom. It is just upstream and west of where the stream is crossed by the 60-foot fault against which oil has been found on the east, upthrown side, in the Post Oak and Dixie oil pools of Falls County.

[3] Frank Bryan, "Notes on the Archæology of Central Texas," *American Anthropologist* (January-March, 1931).

FIG. 2.—Close detail of unconformable contact at top of buried midden on Tehuacana Creek, McLennan County. Homogeneous material, below broken line in ink, is midden material which extends to depth of 2 feet below water level. Material above broken line is stratified silt. Midden material is very black. Silts are Permian red.

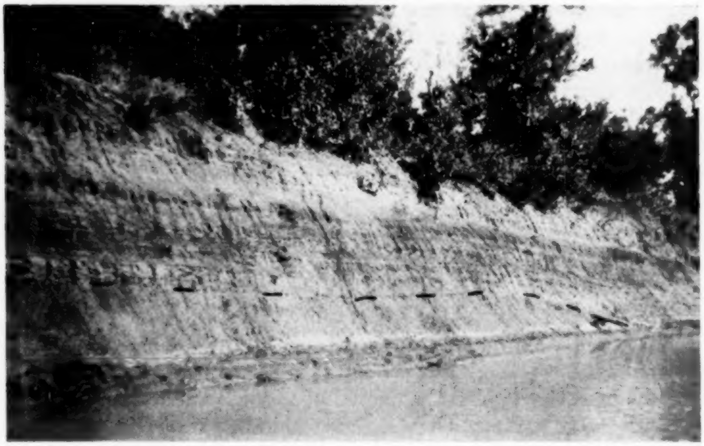


FIG. 3.—Extreme down-dip end of buried midden on Tehuacana Creek and sharp dip in stratified silt above midden which is homogeneous material below broken ink line. Midden material is very black. Silts are Permian red.

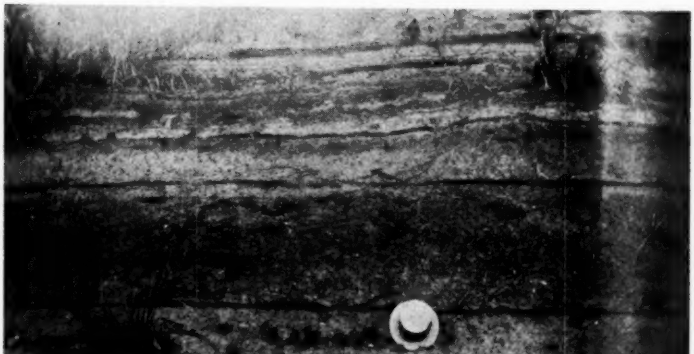
The second one was discovered by the writer in a drainage ditch cut by the Texas Highway Department to straighten Tehuacana Creek where it is crossed by the Waco-Marlin highway, about 5 miles southeast of Waco, McLennan County, Texas. Here there is a total thickness of 7 feet of black midden material, with charcoal and ash extending to a depth of 2 feet below low water level. It is buried, at the thinnest place, beneath 15 feet of stratified red silt, apparently a lake deposit. The thin hard layers, which give this silt its beautifully stratified appearance, are not caused by an actual difference in deposited material. They owe their hardness to the periods when the lake went dry. When one of the hardened layers is carefully cleaned off, the old, hexagonal, dried mud cracks are still plainly seen. This midden is near, and on the downthrown side of, a 120-foot fault. The midden material is underlain with a second 10-foot stratum of the stratified silt.

The third buried midden of this type was discovered by J. E. Pearce of the department of anthropology at the University of Texas. It is in the gravel pit of the Missouri, Kansas, and Texas Railway on the downthrown side of a large fault, just east of where it crosses Brushy Creek at the cheese plant on the north edge of Round Rock, 12 miles north of Austin. Here charcoal, ashes, and finished artifacts have been found to a depth of 18 feet in coarse gravel which, prior to this discovery, was quickly and easily classified as Pleistocene. The presence of man-made implements in these gravels has complicated this former easy correlation. High anthropological authorities are inclined to frown upon any evidence which tends to upset the long-accepted theory of a post-ice age migration of man to the Americas, via Bering Strait.

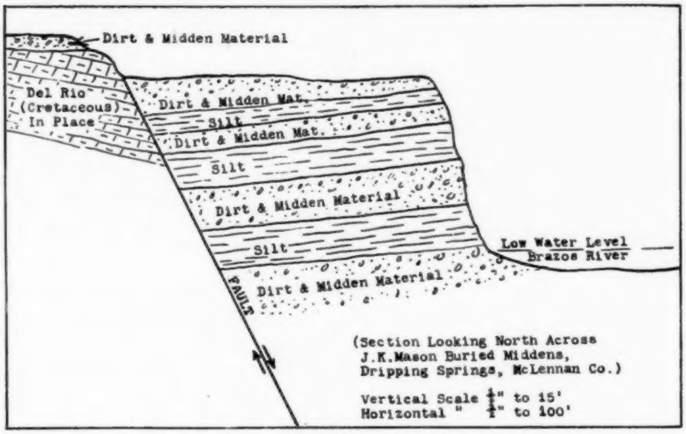
The fourth, and most important, of these buried middens, was discovered by J. K. Mason of Waco, Texas. It is more a series of buried middens than an isolated case. It is located in a steep bank of the Brazos, about 5 miles north of Waco, where the Hawkins Survey adjoins that stream. Here, there are three definite midden levels separated by stratified silts similar to that overlying the midden on the Tehuacana. The lower one was discovered by digging with a post-hole auger. It is 7 feet below low water level and 32 feet below the top of the 25-foot bank which, in turn, is below flood-water level. These stratified deposits of charcoal, ashes, arrowheads, and other midden material are adjacent to, and have, in fact, been faulted down against, undisturbed Cretaceous marls of Del Rio age. There is, at this faulted contact, a typical fault-fissure spring which, in this area of few springs

A

B



C



D

FIG. 4.—J. K. Mason buried midden on Brazos River, McLennan County, Texas. *A*, man's foot is at top of one midden level. Thick stratum off to right and above his head is second midden level. Dark substance at base by box is third. Digging with post-hole auger in this third midden level revealed charcoal, ashes, and other midden material extending to at least 7 feet below low water level. Stratified material between these midden levels is fine silt, not ordinary bottom alluvium. *B*, yard stick here is across second or top midden level shown in *A*. *C*, details of unconformity at top of middle midden level in *A*. Thick bed is filled with midden material and thin layers above are fine silt. In all pictures midden material is ordinary alluvium filled with charcoal and ashes. It is very black. Stratified silts are red in color. *D*, section looking north across buried midden.

and brackish river water, possibly explain the continuous occupancy of the site.

These buried middens have been discussed in detail in previous papers by the writer.[4] Details are not given here except to stress the points which these middens have in common. All are near, and on the downthrown side of, faults. All have large quantities of light charcoal and ash undisturbed by water, even though found below low water level. In all, the midden material is overlain by an entirely different material, the contact being a clean-cut unconformity.

The only estimation as to age that can safely be made at this time, is the identification of an arrowhead taken from the Tehuacana midden. Pearce[5] says that it belongs to a type found in about the upper one-fourth of the great middens he has explored farther south; these

[4] Frank Bryan, *Central Texas Archeol. Soc. Bull. 1–2* (Baylor University, Waco, Texas).

[5] J. E. Pearce, department of anthropology, University of Texas.

middens he estimates to be approximately 10,000 years old. This limits the burial of this midden to not more than 2,500 years ago, thereby destroying any possibility of great antiquity.

As the study of the prehistory of the southwest continues—it is now barely in its infancy—it may some day be possible to fix the age of all artifacts found in these middens to within 500-year periods, since the great majority of artifacts found in New Mexico and Arizona can now have their age accurately fixed, thanks to the splendid work done by Douglas[6] and others in working up a tree-ring calendar for that great area.

However, these buried middens are not the only evidence of Recent or at least post-Pleistocene faulting to be found in central Texas. All geologists contacted, who have attempted to map the surface geology of that part of Texas overlain by beds of Cretaceous and Tertiary age, have arrived at the same conclusion wherever faulting is found, with few exceptions; the picture is complicated by covering deposits of Pleistocene gravels. In several places, thick beds of Pleistocene gravels have apparently been faulted down against beds of Cretaceous age.

The outstanding example of this is the gravel deposit which is being worked for road material near the town of West, McLennan County. This gravel deposit is on the crest of the highest hill in the county. It has apparently been protected in this easily eroded position by being faulted down against the harder Austin chalk, which holds up the protecting escarpment.

Other supporting evidence is the presence of lakes on the downthrown side of faults. The drainage ditch which exposed the buried midden on Cow Bayou was dug to drain a near-by, broad lake. From the time the first settlers came until it was recently drained, there was a large lake parallel with, and on the downthrown side of, the fault exposed by the logs of the wells drilled around the Dixie pool, Falls County. There is still a lake on the downthrown side of a fault which is shown by well logs to cross the B. M. Stiles farm in the J. J. Acosta Survey, near Satin, Falls County.

Earthquake-formed lakes are not uncommon. The outstanding American examples are the St. Francis lakes of northeastern Arkansas and the Reelfoot Lake of northwestern Tennessee, which were formed by the New Madrid earthquake of 1811. The largest of these is more than 20 miles long and 5 miles wide.

Other evidences, suggesting that certain parts of central Texas

[6] A. E. Douglass, "The Secret of the Southwest Solved by Talkative Tree Rings," *Natl. Geog. Mag.*, Vol. 56, No. 6, p. 767.

are not now dormant zones, are the following. In one 18-month period the 42-inch cast iron pipe connecting Lake Waco with the city of Waco broke 36 times within 300 feet of where the line crosses the fault. This is the same fault on which is located the J. K. Mason midden previously described. On August 16, 1931, Waco had an earthquake of sufficient violence to stop clocks and on April 9, 1932, the city of Wortham had an earthquake of sufficient violence to unseat bricks from chimneys.

However, should all these evidences of recent movements along the faults of the Balcones system be discarded, the very shape and character of these grabens and grabens-within-grabens should suggest that they represent the beginning stage of an uplift. Grabens of this type should be expected to be the first apparent surface reflection of deep-seated uplift movement under comparatively soft sediments, such as the Upper Cretaceous and Tertiary of Texas, to which sediments they are apparently confined and in which they are the predominating type of local surface deformation, if not the only widespread type to be found.

If there is a deep-seated upthrust movement buried beneath sediments of the comparatively soft Cretaceous type, in an area the size of only an average oil-producing anticline, the lower beds, loaded beyond their elastic limit, will yield and adjust themselves to the upbulge by flowing into an unbroken anticline. The beds at the surface can only pull apart and, therefore, become faulted, since they have no load of sediments above to cause them to yield by flowing.

The initial stage of such an upthrust would be a comparatively narrow crack or graben. Further upward movement will not continue to widen the first narrow graben. It will, instead, stope or slice back, forming faults parallel with, and including, the first pair, thereby forming the typical graben-within-grabens, so common to the Balcones system. From the very beginning of such an upthrust movement and during its active life, the surface expression will tend to be a collapsed anticline, or a remittent graben.

A local example of this type of anticline is described by Deussen and Andrau.[7] Here the upthrust is furnished by a deep salt plug. Their detailed cross sections give an excellent picture of the stoping back and breaking along new fault planes. This is common to all grabens studied in close detail, being due to a continuous and prolonged upward movement. The only criticism of the sections mentioned is that they show the position of the fault planes by use of the conventional

[7] Alexander Deussen and E. W. K. Andrau, "Orange, Texas, Oil Field," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 20, No. 5 (May, 1936), pp. 531–59.

straight lines. These should be shown for mathematical accuracy by parabolic curves; the resultant of two forces acting at right angles to each other, eventually coming together and forming a large U. The cause of this small, local graben is exactly the same as that resulting in the presence of the large grabens adjacent to the Powell-Mexia line of pools. Except for size, the only difference is in the upthrusting medium which at Orange is due to the salt plug, while at Mexia and Powell, some ancient, pre-Cretaceous mountain range is beginning to suffer a new lease on life. The last conclusion is drawn from the fact that the well nearest the Mexia-Powell graben which penetrated pre-Cretaceous strata (the Humble Oil and Refining Company's Holderman No. 1, at Mt. Calm, Hill County, which is only 20 miles from the nearest point on the graben) went out of the Cretaceous into somewhat softer Silurian shales, uptilted at the mountain-making angle of about 43° from the horizontal.

To say that the great grabens parallel with the Mexia-Powell line of pools are a primary or contributing cause of the accumulation of oil in these pools is hardly a logical statement. To give credit to the east-bordering faults, against which the oil is trapped, is to give credit to the grabens, the collapsed crest of a great anticlinal uplift.

It appears, by logical reasoning, that the stoping back of these faults away from the center of the initial grabens has, instead, destroyed large parts of such prolific pools as Richland, Wortham, and North Currie in particular, if in places whole pools have not been destroyed by being so broken and lowered by faulting that water invaded the sand and dispersed the oil. That this has actually happened is strongly suggested by the presence of oil-stained sands in wells within the graben proper, and especially just across the faults from the aforementioned three pools.

However, the data as to oil-stained sands and so-called "bleeding cores" from wells within the graben near these pools have been gathered by word of mouth from drillers and promoters who have not all been considered reliable observers. One recorded reliable example of an oil pool being partly destroyed by faulting subsequent to the accumulation is that reported in the Van pool by Lahee.[8] It is an open question, however, as to whether the oil in the down-faulted part of the sand, "spilled across to the upthrown side" as Lahee suggests, or whether it was dispersed by the invading water and, for commercial purposes, forever destroyed. The latter interpretation seems the more logical, where the amount of faulting is greater than the thickness of

[8] F. H. Lahee, "Lateral Migration of Oil at Van, Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 20, No. 5 (May, 1936), p. 615.

the sand. The "heaving" clays, both above and below the Woodbine sands, in the present Woodbine pools, are loaded well beyond their crushing strength and form perfect seals across fault planes.

Fault planes do not act as vertical migration channels for oil or mineralized waters except where the rocks faulted are not loaded beyond their elastic limits and, therefore, do not flow in and close the crevices the instant formed. As an example, a fault crevice in quartzite would not begin to seal by flowage at a depth of less than 6 miles, as quartzite has a crushing strength in excess of 30,000 pounds to the square inch, while the Woodbine clays begin to flow under a pressure of less than 1,000 pounds to the square inch. It is for this reason that rich, commercially-important mineral veins are found in fault crevices in only rocks not loaded beyond their crushing strength, and that there are no sizeable mineral veins where soft shales are faulted.

Therefore, taking into consideration the troublesome properties of water, once it is allowed to penetrate an oil-bearing sand, it is easier to believe that any faulting down of oil saturated sands to below water level on a given structure means the total destruction of that part of the sand as a commercial oil-bearing horizon, for water is less viscous than oil. It has not the same tenacious molecular attraction which leaves permanent stains behind. It moves with less friction loss through both porous formations and pipe lines.

To understand the amount of destruction which may have been caused by recent faulting in central Texas alone, it is only necessary to take the one closely drilled area, the Mexia-Powell section, and give it a logical, detailed examination.

In making such an examination, some, perhaps dangerous, assumptions must be made. The first and most important is that the evidence of recent faulting herein submitted is sufficient to justify the examination. The second is that a deep-seated upthrust movement is reflected at the surface in comparatively soft strata in the form of collapsed anticlines or grabens, similar to the example cited by reference to the Orange pool. The third, and most dangerous, is that in the uplift under examination, which is about 50 miles long and 10 miles wide, the deep-seated guiding force is a buried mountain range, similar in character to the Wichita or Arbuckle ranges of Oklahoma, and that the local, oil-producing "highs" on this uplift are the result of local "buried hills" as suggested by the late Sidney Powers.

The facts are: there are six pools which lie in an almost straight line, namely, beginning at the north, Powell, Richland, North Currie, South Currie, Wortham, and Mexia. Each is a local, faulted anticline at the depth of the producing horizon. They vary from less than 2 to

more than 8 miles in length, and from less than 0.5 mile to nearly 2 miles in width. All six pools are bordered on the west by a continuous downfaulted graben, which varies in width from 1 mile to nearly 5 miles, and in depth from less than 100 feet to more than 500 feet. Only one pool has been discovered within the graben proper. This is the Nigger Creek pool, which is so near the west edge, that its surface expression is within the graben, and, due to the hade of the faulting, the oil is west of the surface trace of the west-bordering fault. No pools have been found along the west or up-dip side of the graben. The graben is irregular as to outer borders, has hour-glass type of pinched-in sections, and extends parallel with the strike of the surface beds of Eocene age.

These seven producing pools can be divided into two definite types, when contoured at the level of the producing sand. In one the contours show a typical Mid-Continent anticline with a small amount of the closure faulted off the west edges. Powell, South Currie, and Mexia belong to this type. In the other, the top closing contours are little more than arcs of a circle, picturing only, at best, half an anticline. Richland, North Currie, Wortham, and Nigger Creek belong to this type, and of these, North Currie deserves special mention in that only two small remnants of the oil-bearing part of the "high" remain intact, in neither of which there are more than 40 acres of production.

On the assumption that the faulting is recent and had nothing to do with the accumulation, which appears to be typically anticlinal, if the contours are projected across the faults to conform with normal structures of this type, the amount of producing acreage destroyed by faulting can be estimated to be about as follows.

Structure	*Acreage Destroyed Percentage*	*Structure*	*Acreage Destroyed Percentage*
Powell	20	Wortham	50
Richland	50	Mexia	25
North Currie	80	Nigger Creek	50
South Currie	25		

To this could probably be added several whole pools of the size of Wortham or Richland, for many wells drilled by wildcatters near the center of the graben, regardless of the geology of the locations, reported encouraging oil showings. Several thought that they had producing wells until tested. Three well known examples are: the so-called Jap well, west of Wortham; the Clayton well, half-way between Wortham and Tehuacana, in almost the exact center of the graben;

and the Hornbeck well, just east of Tehuacana and near the west edge of the graben.

This assumed partial and complete destruction of possible commercial oil pools by faulting rests, first, on the evidence presented that the faulting is comparatively recent and, second, that a deep-seated upthrust into soft strata, whether it be a buried hill of indurated rock or a salt plug, will, in the zone where the stratum is loaded beyond its elastic limit, cause anticlines or domes to form, but that near the surface the necessary stretching of the formations to form the anticlinal arch will cause them to pull apart and leave, as surface and near-surface expressions, fault grabens similar to those which reach to the depth of the producing sands in the Orange and Conroe pools.

If these assumptions are correct, advantage can be taken of them in future exploration work. Particularly is this true in testing for oil on deep "highs" located by a seismograph survey. It is the custom to test such structures near the center and a great many cores of oil-stained sands have been taken, but the structures were disappointing failures. In such structures, it is quite possible for the down-faulted graben, as at Orange, to have been of such a depth that water has entered the sand and dispersed the oil. More detailed shooting and a careful weighing of all the factors might suggest that it is better to make the original test on a shoulder, rather than in the center of such structures.

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GEOLOGICAL NOTES

SEARCH FOR OIL IN MÜREFTE, TURKEY[1]

The drilling activity of the petroleum group of the Maden Tetkik ve Arama Institute at Mürefte began in 1935. During the 6 summer months, 4 shallow wells (55–135 meters in depth) were drilled in the vicinity of Hoşköy on the Marmora Sea. The drilling was near an old well which was reported to have produced some oil previously.

Mürefte is 81 miles from Istanbul on the European shore of the Marmora. The rise from the sea to the top of the Eocene limestone is fairly abrupt. Mount Elie, an overthrust block capped with this limestone, is 680 meters high and only 5 kilometers from the shore. The structural conditions in front of the overthrust mass are obscured by numerous landslides. Some minor folds, however, are observed. The places where these are intersected by cross faulting are considered to offer possibilities of small traps for oil and gas. The Miocene sediments overlying the area are sands, marls, and shales, some of which show oil at Isterne Dere and at a branch flowing into Hora Dere.

Two of the wells drilled near Hora Dere, last year, had showings of oil, but all the wells contained salt water in quantity. The work then was suspended for the winter pending the acquisition of additional drilling material. The new equipment, which consists of a Star machine, powered with a 90-horsepower Waukesha engine, was supplemented with a steel derrick, 20 meters high, made in Turkey. This well, located near Mürefte was started April 24. It showed some oil between 82 and 84 meters and some gas between 115 and 116 meters in depth. On going deeper, caving troubles necessitated the use of casing and 121.5 meters of $8\frac{1}{4}$-inch casing was lowered. On May 8, at 125.9 meters, a flow of gas, estimated at 3 million cubic feet (85,000 cubic meters), pushing the tools and ejecting the mud to the crown block, was encountered. The gas flowed freely for 5 days, and pressure decreased. When it was measured at the end of this period, it showed 600,000 cubic feet (17,000 cubic meters). On lowering the tools, it was discovered that a bridge had formed. After removing this, the flow increased to 1.8 million cubic feet (51,000 cubic meters). The following morning, a third measurement showed

[1] Cevat Eyüb Taşman, "Müreftede Petrol Aramalari" (Search for Oil in Mürefte), *Maden Tetkik ve Arama*, Enstitüsü Yayini (Ankara, Turkey), Sayi 3 (Temmuz, 1936), excerpt from pp. 21, 22.

the gas flow to be 1 million cubic feet (28,000 cubic meters). The gas is wet, but the benzine content has not yet been determined. On drilling farther, a flow of brackish water was encountered between 147.5 and 150 meters in depth. The water rose 70 meters, but later subsided below the gas horizon.

The significance of this phenomenon in Mürefte may be summed up in the statement that the Upper Tertiary deposits of the region are petroliferous and that the deeper sands may contain oil or gas in commercial quantity. However, the error must be avoided that such accumulation necessarily exists. It is simply a good sign encouraging further exploration.

CEVAT EYÜB TAŞMAN

ANKARA, TURKEY

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
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REVIEWS AND NEW PUBLICATIONS

* Subjects indicated by asterisk are in the Association library and available to members and associates.

Principles of Structural Geology. By CHARLES MERRICK NEVIN. Second edition. John Wiley and Sons, Inc., New York (1936). 348 pp., 163 illus. Price, $3.50, plus postage.

The first edition of Professor Nevin's work was published in 1931 and was reviewed by John L. Rich in the *Bulletin*, Vol. 15, No. 11 (November, 1931), page 1399. In his preface to the second edition, Nevin says:

> This edition represents no departure from the former method of treatment. The book is still primarily for beginning students, and for this reason, references to foreign literature and to papers not readily accessible are seldom given. During the past five years, intensive research and field work have thrown so much light on the problems of structural geology that thorough revision of the first edition has been necessary in many places. Because of numerous requests, a new chapter, "Structures Associated with Igneous Intrusion" (by Evans B. Mayo) has been added. . . .

The subjects considered and their relative importance, as indicated by the space allotted them, are shown in the following list of the chapter headings: "Physical Properties of Rocks," 12 pages; "Stress and Strain Relations," 20 pages; "Flexures," 53 pages; "Faults," 65 pages; "Joints," 17 pages; "Cleavage," 22 pages; "Structures Associated with Igneous Intrusion," 22 pages; "Structures in Unconsolidated Sediments," 21 pages; "Reflection of Rock Structure in the Topography," 21 pages; "Some Facts, Inferences and Hypotheses Regarding the Earth," 35 pages; "Continents and Ocean Basins," 20 pages; "Mountain Systems," 32 pages.

Although the book is considered to be primarily for beginning students, it is by no means elementary, and is evidently intended for students beginning their specialized training in geology. In places, the language seems to the reviewer to be more involved than is necessary even for mature and professional readers. A background of general geology as well as of physics and mathematics is manifestly a necessary preparation on the part of students who undertake a course based on this text. Most subjects are handled with a degree of detail which will ordinarily be sufficient for petroleum geologists, who may use the book as a reference on structural problems, without their pursuing their research further in the literature. The field of structural geology is, however, rather broadly opened by the 90 general references which are given in lists at the ends of chapters, in addition to about 80 specific references in footnotes.

The application of minor structural features to the working out of major features, the recognition of structural features in the field, and the application of the knowledge of structural conditions to economic geology are features that are emphasized throughout what may be called the factual parts of the book; while an open-minded attitude, though with clear expressions as to the author's inclination, characterizes the treatment of the more theoretical subjects.

Mechanically, the book is very satisfactory. The diagrams are clearly

drawn and have not been subjected to too severe reduction, and the half-tones are excellent reproductions of well chosen photographs.

L. C. SNIDER

NEW YORK CITY
August, 1936

International Geological Congress: Report of the XVI Session, United States of America, 1933. 2 vols., 1342 pp., 82 papers, 68 abstracts, many illus. Published by the Congress, Washington, D. C. (1936). Price, $10.00 per set; $5.00 per volume.

The first 142 pages of Volume I are given to the administrative reports of the Congress. The remainder of Volume I and all of Volume II consist of papers and abstracts of papers delivered at the session, which was held at Washington, July 22–29, inclusive, 1933. The scientific communications are grouped according to principal themes of interest as follows.

1. "Measurement of Geologic Time by Any Method," 7 papers (1 in German), 4 abstracts, 91 pp.
2. "Batholiths and Related Intrusives," 15 papers (1 in Italian), 3 abstracts, 164 pp.
3. "Zonal Relations of Metalliferous Deposits," 5 papers (3 in German), 4 abstracts, 62 pp.
4. "Major Divisions of the Paleozoic Era," 18 papers (1 in German), 4 abstracts, 238 pp.
5. "Geomorphogenic Processes in Arid Regions and Their Resulting Forms and Products," 8 papers (2 in German and 1 in Italian), 4 abstracts, 79 pp.
6. "Fossil Man and Contemporary Faunas," 4 papers (1 in French), 5 abstracts, 131 pp.
7. "Orogenesis," 16 papers (1 in German, 1 in French, and 1 in Italian), 15 abstracts, 198 pp.
8. "Geology of Petroleum," 11 abstracts, 6 pp.
9. "Geology of Copper Deposits," 1 paper (in Spanish), 3 abstracts, 17 pp.
10. "Miscellaneous Papers," 8 papers (3 in French, 2 in Italian, 1 in Spanish, and 1 in German), 15 abstracts, 81 pp.
11. "Report of the Commission on the Distribution of the Karroo (Gondwana) System," 31 pp.
12. "Report of the Commission on Fossil Man," 195 pp.

All papers except those otherwise noted are in English, and English abstracts are given for all papers. Discussions are given in the language used by the speakers.

The report closes with an announcement of the publication of a 2-volume report on the *Copper Resources of the World*, in December, 1935. It has been the custom of the Congress since the 11th (Swedish) session to publish a comprehensive survey of world resources of some mineral. The resource originally chosen for the 16th session was petroleum, but subsequent investigation showed that this resource was so fully covered in recent publications and in others in preparation that it was felt that the Congress could be of greater service if another topic were selected. It was therefore decided to prepare, instead, a volume on the copper resources of the world.

The papers presented on the "Geology of Petroleum" are, as has been noted, represented only by abstracts. All but one have been published. These papers are as follows.

1. "Tectonica y acumulaciones petroliferas," by J. A. Broggi (*Bol. Soc. Geol. Peru*, Vol. 6, Fasc. 1, 1934).
2. "Tectonics of the Southeastern Caucasus and Its Relation to Productive Oil

Fields," by I. M. Goubkin (*Bull. Amer. Assoc. Petrol. Geol.*, Vol. 18, No. 5, pp. 603–71, 1934).

3. "Orogenesis and Paleogeography of the Hungarian Basin System," by L. de Lóczy (published under title, "Tectonics and Paleogeography of the Basin System of Hungary, Elucidated by Drilling for Oil," *ibid.*, Vol. 18, No. 7, pp. 925–41, 1934).

4. "Studies in Paleogeography," by A. I. Levorsen (*ibid.*, Vol. 17, No. 9, pp. 1107–32, 1933).

5. "Origin and Accumulation of Oil," by Frank R. Clark (*Problems of Petroleum Geology*, pp. 309–35, Amer. Assoc. Petrol. Geol., 1934).

6. "Experimental Studies Bearing on the Origin of Petroleum," by Taisia Stadnichenko (unpublished).

7. "Hydrogenation and the Origin of Oil," by W. E. Pratt (*Problems of Petroleum Geology*, pp. 235–45, Amer. Assoc. Petrol. Geol., 1934).

8. "The Limestone Reservoir Rocks of Mexico, with a Discussion of the Source of the Oil," by J. M. Muir (*ibid.*, pp. 377–98).

9. "The Ponto-Caspian and Mediterranean Type of Oil Deposits," by Stanislav Zuber (*Bull. Amer. Assoc. Petrol. Geol.*, Vol. 18, No. 6, pp. 760–76, 1934).

10. "Paleogeography of the Oil-Bearing Deposits in the Ponto-Caspian Countries," by Stanislav Zuber (*ibid.*, pp. 777–85).

11. "Some Studies of Source Beds of Petroleum," by Parker D. Trask (substance published in *Origin and Environment of Source Beds of Petroleum*, by P. D. Trask assisted by H. E. Hammar and C. C. Wu, Gulf Publishing Co., Houston, Texas, 1932; also in articles by P. D. Trask in *Oil and Gas Jour.*, Vol. 33, Nos. 27, 28, and 29, 1934).

Besides the papers on petroleum geology mentioned, it may be noted that the substance of the papers, "A Geophysical Survey of Southern Bavaria," by Donald C. Barton; "Structural Relations of the Ouachita Geosyncline of Arkansas, Oklahoma, and Adjacent States," by H. D. Miser; and the complete paper, "Structural History of the Arbuckle Mountains, Oklahoma, in Pennsylvanian Time," by Robert Dott, were published in this *Bulletin* during 1934. These three papers are represented in the *Report* of the Congress only by abstracts.

The subject matter of many papers, particularly those in the groups on "Measurement of Geologic Time by Any Method," "Batholiths and Related Intrusives," "Zonal Relations of Metalliferous Deposits," and "Fossil Man and Contemporary Faunas," is so far removed from the field of petroleum geology that petroleum geologists will find little of professional interest in them, though, of course, they are of general geologic interest. Many of the papers in the groups devoted to "Orogenesis" and to the "Major Divisions of the Paleozoic Era" are of direct interest to petroleum geologists who have problems in general structural and stratigraphic geology.

These two volumes, together with the *Guidebooks* to the excursions, the *Geological Map of the United States*, and the volumes on the *Copper Resources of the World*, represent an enormous amount of labor on the part of the organization committee of the XVI Session of the International Geological Congress and the many geologists who coöperated with the committee, and constitute a most valuable contribution to the literature and science of geology.

L. C. SNIDER

NEW YORK CITY
September, 1936

Ferdinand Roemer, Texas (Bonn, 1849). Translated by O. Mueller, 746 East 6½ St., Houston, Texas. Standard Printing Company, San Antonio, Texas (1935). xii+301 pp., 1 map of Texas. Price, $3.00 postpaid.

The first sixth of the book is a summarized report on the physical geography, plant, animal and mineral products, inhabitants, and German colo-

nization, of Texas. The principal part of the book is a continuous travelog of Roemer's sojourn in Texas. His scholarly, and more formal, report of his geological studies in Texas was embraced in his "Die Kniedebildungen von Texas und ihre organischen Einschluesse." However, the travelog contains his day-to-day observations and comments on the geology along his route. Although not primarily geological, this vivid account of a geological trip almost a century ago makes interesting reading.

DONALD C. BARTON

HOUSTON, TEXAS
August, 1936

RECENT PUBLICATIONS

ARKANSAS-LOUISIANA

*"Northern Rim of Coastal Plain Contains Untapped Reserves," by L. G. E. Bignell. *Oil and Gas Jour.* (Tulsa), Vol. 35, No. 16 (September 3, 1936), pp. 11, 12; 3 illus. Résumé of geology from W. C. Spooner's "Oil and Gas Geology of the Gulf Coastal Plain in Arkansas." General structure and oil-field map by T. W. Leach.

ASIA MINOR

*"Das Erdöl Kleinasiens" (Petroleum in Asia Minor), by B. Granigg. *Zeit. praktische Geol.* (Halle—Saale, Germany), Vol. 44, No. 7 (July, 1936), pp. 101–04; 1 illus.

BRAZIL

*"Reconhecimento geologico nos Rios Tocantins e Araguaya" (Geological Reconnaissance along the Rivers Tocantins and Araguaya), by Axel Löfgren. *Ministerio da Agricultura, Serv. Geol. e Mineral.* (Rio de Janeiro, Brazil) *Bol. 80* (1936). 61 pp., many illus., diagrams, and maps.

FRANCE

*"Der Tiefbau auf Erdöl in Pechelbronn (Elsass)" (Deep Mining of Petroleum in Pechelbronn, Alsace). *Kali* (Halle—Saale), Vol. 30, No. 15 (August 1, 1936), pp. 144–46.

GENERAL

*"Deformation of Rocks under High Confining Pressures," by David T. Griggs. *Jour. Geol.* (Chicago), Vol. 44, No. 5 (July–August, 1936), pp. 541–77; 14 figs., 5 pls.

Minerals Yearbook, 1936, U. S. Bureau of Mines. 1089 pp., 69 chaps., 154 illus. May be purchased from Superintendent of Documents, Washington, D. C. Price, $2.00. Data regarding the operation of the mineral industry of the United States in 1935 are given and interpreted. Chapters on petroleum and natural gas.

Petroleum Technology, 1935, Inst. Petrol. Tech. (Aldine House, Bedford St., Strand, London, W. C. 2). viii+263 pp., 6 illus. Cloth. Price, 7s. 6d. (post free, 8s.). A comprehensive summary of developments in petroleum technology during 1935, containing more than 2,000 references to publications on petroleum and cognate subjects.

INDIA

*"Note on an Occurrence of Natural Gas at Gogha, Kathiawar," by P. K. Ghosh. *Records Geol. Survey India* (Calcutta), Vol. 69, Pt. 4 (1936), pp. 426–38; 1 pl.

LOUISIANA

*"Louisiana Vicksburg Oligocene Ostracoda," by Henry V. Howe and John Law. *Louisiana Dept. Conservation* (New Orleans) *Geol. Bull. 7* (August 18, 1936). 96 pp., 6 pls. including 186 figs.

MEXICO

*"Evolution of the Coahuila Peninsula, Mexico." *Bull. Geol. Soc. America* (New York), Vol. 47, No. 7 (July 31, 1936), pp. 969–1176.

Part I. "Relation of Structure, Stratigraphy, and Igneous Activity to an Early Continental Margin," by L. B. Kellum, R. W. Imlay, and W. G. Kane. Pp. 969–1008; 3 figs., 3 pls.

Part II. "Geology of the Mountains Bordering the Valleys of Acatita and Las Delicias," by W. A. Kelly. Pp. 1009–38; 2 figs., 13 pls.

Part III. "Geology of the Mountains West of the Laguna District," by Lewis B. Kellum. Pp. 1039–90; 2 figs., 14 pls.

Part IV. "Geology of the Western Part of the Sierra de Parras," by Ralph W. Imlay. Pp. 1091–1152; 3 figs., 10 pls.

Part V. "Igneous Phenomena and Geologic Structure near Mapimi," by Quentin D. Singewald. Pp. 1153–76; 1 fig., 5 pls.

MICHIGAN

*"Operators in Michigan Face Troubles When Drilling to Deeper Strata," by W. T. Ziegenhain. *Oil and Gas Jour.*, Vol. 35, No. 16 (September 3, 1936), pp. 26, 27; 2 illus. Oil-pool map and geologic section by Michigan Geological Survey Division.

*"Geology of Crystal Field Shows Importance of Folding in Oil Accumulation," by G. E. Eddy. *Ibid.*, pp. 32, 35, 38; 4 illus. Data of Michigan Geological Survey, Gulf Refining Company, Michigan Pacific Oil and Gas Company, and others.

MONTANA

*"Devonian Rocks in the Big Snowy Mountains, Montana," by Charles Deiss. *Jour. Geol.*, Vol. 44, No. 5 (July–August, 1936), pp. 639–44; 3 figs.

NEBRASKA

*"The Ostracoda of the Missouri Series in Nebraska," by W. R. Johnson. *Nebraska Geol. Survey* (Lincoln) *Paper 11* (1936). 52 pp., 5 pls. (93 figs.).

NEW MEXICO

*"Stratigraphical Geology," by Charles Keyes. *Pan-American Geologist* (Des Moines, Iowa), Vol. 66, No. 1 (August, 1936), pp. 69–80; 1 fig.

PENNSYLVANIA

*"The Onondaga Formation in Pennsylvania," by Bradford Willard. *Jour. Geol.*, Vol. 44, No. 5 (July–August, 1936), pp. 578–603; 5 figs., 7 tables.

RUSSIA

*"Tectogenetic Phases of the Telbess District of Gornaya Shoriya," by V. S. Baturin. *Problems of Soviet Geology* (Moscow), Vol. 6, No. 7 (July, 1936), pp 555–78; 4 figs., 4 tables. In Russian. Summary in English.

*"On the Younger Relief of the Altai and the Ancient Valleys of Kasakhstan," by V. P. Nekhoroshev. *Ibid.*, pp. 579–89; 4 figs. In Russian.

*"Contributions to the Question of the Central Asiatic Lower Paleogene," by O. S. Vialov. *Ibid.*, pp. 590–97. In Russian.

*"On the Silurian Massif of Podolia," by N. I. Larin. *Ibid.*, 598–612; 2 figs. In Russian. Summary in English.

*"On Some Questions concerning the Carboniferous Stratigraphy of the Western Slope of the Southern Ural," by G. I. Theodorovitch. *Ibid.*, pp 613–17. In Russian.

TEXAS

**Oil and Gas Jour.*, Vol. 35, No. 14 (August 20, 1936), pp. 54–102, has several articles dealing with the oil and gas fields in the Corpus Christi area. "Subsurface Geology in Saxet Field," pp. 72–74; 4 illus. "Geology of White Point Field Requires Careful Drilling," pp. 75–76. "Plymouth Field, Corpus Christi Area, Example of Orderly Development," pp. 100–02.

"New Upper Cretaceous Ostreidae from the Gulf Region," by L. W. Stephenson. *U. S. Geol. Survey Prof. Paper 186-A.*, pp. i–ii, 1–12; 3 pls. Price, 5 cents. May be purchased from Supt. of Documents, Gov't. Printing Office, Washington, D. C.

"Geology and Ground-Water Resources of Uvalde and Medina Counties, Texas," by A. N. Sayre. *Ibid.*, *Water-Supply Paper 678*. v, 146 pp., 11 pls., 3 figs. Price, 35 cents. Supt. of Documents, Gov't. Printing Office, Washington, D. C.

"Water Resources of the Edwards Limestone in the San Antonio Area, Texas," by Penn Livingston, A. N. Sayre, and W. N. White. *Ibid.*, *Water-Supply Paper 773-B*, pp. i–ii, 59–113; Pl. 5, Figs. 6–9. Price, 10 cents. Supt. of Documents, Gov't. Printing Office, Washington, D. C.

*"Paluxy Sand in Sulphur Bluff Pool Is Scheduled for Slow Development," by L. E. Bredberg. *Oil and Gas Jour.*, Vol. 35, No. 16 (September 3, 1936), pp. 15, 18; 4 illus. Structure-contour map on Pecan Gap chalk by Claude F. Dally.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 20, NO. 10 (OCTOBER, 1936), PP. 1380-1381

RESEARCH NOTES

ASSOCIATION RESEARCH COMMITTEE

(Members' terms expire immediately after annual Association meetings of the years shown)

D. C. Barton (1936), *chairman*, Humble Building, Houston, Texas
H. W. Hoots (1936), *vice-chairman*, Union Oil Building, Los Angeles, California
M. G. Cheney (1937), *vice-chairman*, Coleman, Texas

Robert H. Dott (1937)	John G. Bartram (1938)	Glenn H. Bowes (1939)
K. C. Heald (1937)	C. E. Dobbin (1938)	W. L. Goldston (1939)
F. H. Lahee (1937)	Stanley C. Herold (1938)	W. C. Spooner (1939)
H. A. Ley (1937)	Theodore A. Link (1938)	Parker D. Trask (1939)
R. C. Moore (1937)	C. V. Millikan (1938)	
F. B. Plummer (1937)	John L. Rich (1938)	
	C. W. Tomlinson (1938)	

The purpose of the research committee is the advancement of research within the field of petroleum geology. If members working actively in research on particular problems care to register with the research committee, the committee will be glad to aid them in any way it can and put them in touch with other men who are, or have been, working on similar or allied problems and can perhaps effect some integration of the research work of the Association. If the younger, or older, members of the Association, who are doing or preparing research for publication, will come to any member of the committee, he will be very glad to offer whatever advice, counsel, or criticism he can in regard to the research, its prosecution, or its preparation for formal presentation. The committee would be glad to have members formulate and present to it suggestions in regard to research problems and programs.

RESEARCH COMMITTEE AT LOS ANGELES, MARCH, 1937

The key topic at the round-table discussion of the research committee at the twenty-second annual meeting of the Association, at Los Angeles next March, is to be "The Origin of Oil."

The leader of the discussion is to be Parker D. Trask. In the following list, he has outlined the more important aspects of the problem, which might merit consideration at that round table.

1. Geographical conditions of deposition of source beds (continental, brackish, near-shore marine, etc.).

2. Original nature of source material (land plants, organic matter in solution in river water entering basins where source material is deposited, marine plant plankton, attached marine plants).

3. Actual nature of source material (remains of bottom-living organisms, remains of nektonic or planktonic organisms, faecal matter of organisms living in environment where source material collects).

4. Changes in chemical composition of source material during the time between its formation in some plant to its burial in a rock for several million years.

5. Inferences on origin of oil based on chemical composition of crude oils (this would include evolutionary changes in petroleums after they had been formed).

6. Influence of time, temperature, and pressure on source materials after they had been buried in the sediments.

7. Influence of catalysts, including methylation and polymerization.

8. Effect of bacteria.

9. Time of formation of oil, including possibility of recurrent crops of oil from same source beds.

10. Relation of diastrophism.

11. Chemical nature of source material (fats, proteins, celluloses, etc.).

12. Quantitative aspects of source material (how much needed and from how big an area).

13. Miscellaneous aspects, such as distillation theories, color of source beds, adsorption.

14. Nature of containing rocks (sand, sandy shale, shale, limestone, etc.).

15. Recent foreign thought on origin of oil.

DONALD C. BARTON
Chairman, research committee

HOUSTON, TEXAS
September 1, 1936

Winter vista, Southern California: oranges and snow-capped mountains.

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THE ASSOCIATION ROUND TABLE

MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The executive committee has approved for publication the names of the following candidates for membership in the Association. This does not constitute an election, but places the names before the membership at large. If any member has information bearing on the qualifications of these nominees, he should send it promptly to the Executive Committee, Box 1852, Tulsa, Oklahoma. (Names of sponsors are placed beneath the name of each nominee.)

FOR ACTIVE MEMBERSHIP

René Pomeyrol, Paris, France
J. P. McCulloch, James Terry Duce, R. F. Baker

FOR ASSOCIATE MEMBERSHIP

Norval Wallace Nichols, New Haven, Conn.
E. DeGolyer, Kenneth Dale Owen, J. C. Karcher
Paul McClure Tucker, Calgary, Alta., Canada
S. Zimerman, Stuart Sherar, Theo. A. Link

FOR TRANSFER TO ACTIVE MEMBERSHIP

William Harlan Taylor, Oklahoma City, Okla.
C. E. Decker, C. W. Tomlinson, Vaughn W. Russom
Fritz E. von Estorff, Batavia-Centrum, Java, D. E. I.
R. N. Nelson, Thomas W. Koch, James P. Bailey

TWENTY-SECOND ANNUAL MEETING, LOS ANGELES, MARCH 17, 18, 19, 1937

President R. D. Reed has announced the dates of the twenty-second annual meeting of the Association: March 17, 18, and 19, 1937, at the Los Angeles-Biltmore Hotel, Los Angeles, California. These dates are Wednesday, Thursday, and Friday, instead of the usual Thursday-Friday-Saturday convention period, so that Mid-Continent and distant members and friends may use the week-ends to travel to and from Los Angeles, thus being absent from their offices only one week of working days. This arrangement should appeal strongly to distant members and result in a large attendance from points east of the Rockies. Exceptionally low rail rates will be available, with stop-over and diverse-route privileges. Several local committees have been appointed and plans are already being made. R. M. Barnes is chairman of publicity and Mrs. W. S. W. Kew is chairman of ladies activities. This early preliminary announcement is made to give members ample time to arrange their vacations or leaves of absence to enjoy the hospitality of the Pacific Section and to profit professionally from the technical program at Los Angeles, March 17, 18, and 19, 1937. Frank A. Morgan, Rio Grande Oil Company, is general chairman.

ASSOCIATION COMMITTEES

EXECUTIVE COMMITTEE

Ralph D. Reed, *chairman*, Los Angeles, California
Chas. H. Row, *secretary*, San Antonio, Texas
A. I. Levorsen, Tulsa, Oklahoma
C. E. Dobbin, Denver, Colorado
L. C. Snider, New York, N.Y.

GENERAL BUSINESS COMMITTEE

Arthur A. Baker (1938)
R. F. Baker (1937)
William A. Baker (1937)
Roy M. Barnes (1937)
Robert L. Cannon (1937)
C. G. Carlson (1938)
Ira H. Cram (1937)
Thornton Davis (1937)
Frank W. DeWolf (1937)
C. E. Dobbin (1937)
J. Brian Eby (1938)
H. B. Fuqua (1937)
L. W. Henry (1937)
Harold W. Hoots (1938)
J. Harlan Johnson (1937
James W. Kisling, Jr. (1937)
A. I. Levorsen (1937)
Theodore A. Link (1937)
Gerald C. Maddox (1937)
J. J. Maucini (1938)
James G. Montgomery, Jr. (1937)
Kenneth Dale Owen (1937)
Ralph D. Reed (1938)
R. E. Rettger (1938)
Chas. H. Row (1937)
G. W. Schneider (1937)
Gayle Scott (1937)
E. F. Shea (1937)
L. C. Snider (1937)
Clare J. Stafford (1937)
J. D. Thompson, Jr. (1938)
Louis N. Waterfall (1937)
Gerald H. Westby (1937)
Maynard P. White (1937)
Neil H. Wills (1937)

RESEARCH COMMITTEE

Donald C. Barton (1939), *chairman*, Humble Oil and Refining Company, Houston, Texas
Harold W. Hoots (1939), *vice-chairman*, Union Oil Company, Los Angeles, California
M. G. Cheney (1937), *vice-chairman*, Coleman, Texas

Robert H. Dott (1937)
K. C. Heald (1937)
F. H. Lahee (1937)
H. A. Ley (1937)
R. C. Moore (1937)
F. B. Plummer (1937)
John G. Bartram (1938)
C. E. Dobbin (1938)
Stanley C. Herold (1938)
Theodore A. Link (1938)
C. V. Millikan (1938)
John L. Rich (1938)
C. W. Tomlinson (1938)
Glenn H. Bowes (1939)
W. L. Goldston (1939)
W. C. Spooner (1939)
Parker D. Trask (1939

REPRESENTATIVE ON DIVISION OF GEOLOGY AND GEOGRAPHY NATIONAL RESEARCH COUNCIL

Frederic H. Lahee (1937)

GEOLOGIC NAMES AND CORRELATIONS COMMITTEE

Ira H. Cram, *chairman*, Pure Oil Company, Tulsa, Oklahoma

John G. Bartram
M. G. Cheney
Alexander Deussen
B. F. Hake
G. D. Hanna
M. C. Israelsky
A. I. Levorsen
C. L. Moody
R. C. Moore
Ed. W. Owen
J. R. Reeves
Allen C. Tester
W. A. Thomas

TRUSTEES OF REVOLVING PUBLICATION FUND

Ralph D. Reed (1937)
Ben F. Hake (1938)
J. V. Howell (1939)

TRUSTEES OF RESEARCH FUND

G. C. Gester (1937)
A. A. Baker (1938)
Alex W. McCoy (1939)

FINANCE COMMITTEE

E. DeGolyer (1937)
Thomas S. Harrison (1938)
W. B. Heroy (1939)

COMMITTEE ON APPLICATIONS OF GEOLOGY

Frank Rinker Clark, *chairman*, Box 981, Tulsa, Oklahoma

William H. Atkinson
Arthur E. Brainerd
Ira Otho Brown
Hal P. Bybee
Carey Croneis
H. B. Hill
Earl P. Hindes
Marvin Lee
S. E. Slipper
H. S. McQueen
E. K. Soper
J. M. Vetter

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Memorial

ARTHUR SIDNEY HENLEY

Arthur Sidney Henley was born on July 3, 1879, in Covelo, California, and passed away on September 5, 1936, at his home, 1700 Grand View Avenue, Glendale, California.

Henley's life was typical of many successful American mining engineers who built on a foundation of sterling character and rigid integrity. His professional activities carried him from the Arctic in Alaska to the tropics in Venezuela, interspersed with long sojourns in the mining camps of California and Nevada.

After experience in various types of mining operations, he finally devoted himself entirely to the oil business about 20 years ago. He made geological examinations in many parts of Oklahoma, Texas, and neighboring states. His efforts met with particular success at Houston, Texas, where, as head of the geological and land departments of the Houston Oil Company, he was responsible for selecting lands which were in a large measure the basis of the company's subsequent growth and prosperity. He was the discoverer of the Lucas field in Live Oak County, Texas.

Ill health caused his retirement from active work several years ago and he returned to his native state, California. He was able to regain a fair measure of health and had entirely recovered from the ills which had caused his retirement. Death finally came from heart failure.

Stanford University was Henley's alma mater, where he was known to all as "Pike." He was a member of the class of 1904 in geology and mining. In the year 1913 he was married to Constance M. Jordan who survives him, together with two children, Arthur S. Henley, Jr., and Ruth.

Henley was long a member of the American Institute of Mining and Metallurgical Engineers and the American Association of Petroleum Geologists.

A wide circle of friends regret his passing, but reflect with satisfaction upon the untarnished professional record he leaves. Those who knew him intimately admire him most as a loving father and husband.

R. P. McLaughlin

Los Angeles, California
September 16, 1936

CORRECTION

The biography of Wilson Keyes, printed on pages 1272–73 of the September *Bulletin*, was prepared by J. H. McClure instead of Cary P. Butcher.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 20, NO. 10 (OCTOBER, 1936), PP. 1385-1388

AT HOME AND ABROAD

CURRENT NEWS AND PERSONAL ITEMS OF THE PROFESSION

E. J. BARRAGY has accepted a position on the geological staff of the Texas Gulf Producing Company, Houston, Texas.

WILLARD F. BAILEY, formerly with the geological department of The Texas Company, is now in the geological department of the Skelly Oil Company, Box 1485, Midland, Texas.

TOM PETTY, district geologist for the Humble Oil and Refining Company, Cisco, is being transferred to Wichita Falls, Texas, where the company is moving its land, scouting, and geological offices from Cisco.

VICTOR COTNER, chief geologist for the Columbian Carbon Company, has moved his headquarters from Amarillo, Texas, to New York. His address is 41 East 42nd Street, New York, New York.

E. H. SELLARDS, professor of geology in the graduate school of the University of Texas, has been appointed research professor for 1936–37. Each year the Board of Regents selects a faculty member for this honor. At the end of the year, he presents lectures of both general and technical interest, embodying the results of his work.

HAL P. BYBEE's new address is 18 Enfield Road, Austin, Texas.

C. WIEDENMAYER, having spent 15 years with the Standard Oil Company of Venezuela, Caripito, is returning to Switzerland where his address will be Lenzgasse 34, Basel, Switzerland.

JACK POOL has been transferred to the geological department of the newly established southwest Texas division of the Barnsdall Oil Company, Nixon Building, Corpus Christi.

HENRY M. KILIAN has changed his address from 815 Chautauqua Street, Norman, Oklahoma, to 837 West 36th Place, Los Angeles, California.

CLEMENTE GONZALEZ DE JUANA has been transferred from the Standard Oil Company of Venezuela to the eastern branch of the Compañia Española de Petroleos, Maturin, Venezuela, South America. He has been appointed district manager.

D. GLYNN JONES has resigned from his position with the Compania Terrocarrilera de Petroleo, Argentina, and joined the staff of Petroleum Concessions Ltd., Haifa, Palestine.

JAMES I. DANIELS, geologist with Pryor and Lockhart, is now living at 211 North Oliver, Wichita, Kansas.

RODERIC CRANDALL, of Crandall and Osmond, announces the change of address of the Crandall and Osmond office from 17 Battery Place, New York

City, to 2005–6 Fort Worth National Bank Building, Fort Worth, Texas. CRANDALL has opened an office at Roswell, New Mexico, also.

C. N. HOUSH and E. G. THOMPSON, of Housh and Thompson, Incorporated, have added a new member to their organization, A. W. SCHOFIELD, who recently resigned from the Gulf Oil Corporation. The new company, Housh-Schofield-Thompson Drilling Company, will do contract drilling work and develop its own properties at Talco and Rodessa.

DEAN EDDY WINCHESTER, petroleum geologist of Denver, Colorado, died September 1, at Eads, Colorado. A ruptured appendix was the cause of his death.

ANDREW COWPER LAWSON, professor of geology emeritus at the University of California, has been awarded the Hayden Memorial Geological Award of the Academy of Natural Sciences of Philadelphia.

A. C. BOYLE, JR., formerly chief geologist of the Union Pacific Railway System, has been appointed acting custodian of Dinosaur National Monument, Jensen, Utah. He is also project superintendent and geological engineer in charge of the operations at the quarry site. The National Park Service, Washington, D. C., is sponsoring the development of the monument.

E. H. FINCH of San Antonio, Texas, is in Cuba for the Sinclair Cuban Oil Company of South America. His address is Apartado 2569, Havana.

JOSIAH TAYLOR, geophysicist, recently with Seismograph Service Corporation of Tulsa, Oklahoma, has opened offices in 912 Giddens-Lane Building, Shreveport, Louisiana. He will specialize in reinterpretation work and do some general consulting.

PAUL WEAVER, geophysicist for the Gulf Oil Corporation, Houston, was the speaker at a recent meeting of the Houston chapter of the American Institute of Mining and Metallurgical Engineers. His subject was on heaving shale, stressing in particular the possible causes of shale heaves.

L. W. STORM, of the Schlumberger Well Surveying Company, was the speaker at the first fall meeting of the Houston Geological Society, September 3. He discussed some practical uses of the surveys made by his company.

GEORGE OTIS SMITH has been made a special representative of the board of directors of the American Institute of Mining and Metallurgical Engineers. In his official capacity he supplements the activities of President JOHN M. LOVEJOY in attending the meetings of the divisions, and in visiting local sections and affiliated student societies.

GLENN R. V. GRIFFITH has moved from Muskogee, Oklahoma, to Tulsa.

GILBERT W. NOBLE, petroleum engineer, is now connected with the Standard Oil Company of New Jersey, 30 Rockefeller Plaza, New York City.

A. LYNDON BELL, of the Colombian Petroleum Company, Cucuta, is returning to the United States after 3 years in South America. His address will be Fulton, Illinois.

E. A. Obering, district geologist for the Shell Petroleum Corporation, Midland, Texas, sailed September 9 for Holland where he will be stationed at The Hague for one year.

G. S. Hume of Ottawa, Ontario, is mapping the Pekisko Hills area of southern Alberta for the Geological Survey of Canada.

The Society of Petroleum Geophysicists will hold its semi-annual fall meeting at Houston, Texas, November 20–21.

Daniel Rey Vercesi, engineer of the Instituto de Geologia y Perforaciones, Montevideo, Uruguay, has been visiting the oil and gas fields of Europe and America.

Clarence Peckham Dunbar, consulting geologist and petroleum economist, Second National Bank Building, Houston, Texas, is the author of *Louisiana Purchasing Power Handbook* and co-author (with William Hunter Dillard, statistician), of *Houston, 1836–1936, Chronology and Review,* books distributed by the Business Research Service of Houston.

Miss Ellen Posey, paleontologist in the geological department of the Empire Oil and Refining Company at Bartlesville since February, 1930, and Fred Bitgood, combustion engineer with the John Zink Company of Tulsa, Oklahoma, were married on August 22, 1936. They are temporarily located at Houston, Texas.

V. C. Illing of the Royal School of Mines, London, was the guest of the San Antonio Geological Society at an informal dinner in the San Antonio Petroleum Club, August 27. Professor Illing was accompanied by A. R. Denison of Fort Worth.

Withers Clay resides at 1519 East Twentieth Street, Tulsa, Oklahoma. Phone, 3-8369.

The Haloid Company (see advertising page iii), through its president, Gilbert E. Mosher, announces the beginning of a new $75,000 building at Rochester, New York—the second major plant expansion since 1934—to increase manufacturing capacity and to provide space for a modern research department. Branch offices are maintained at San Francisco, Los Angeles, New York, Chicago, Philadelphia, Boston, Detroit, Washington, and Toronto. Exclusive agents are located in Dallas, Washington, and Ottawa.

J. Volney Lewis, regional geologist of the National Park Service, Region IV, has removed his office from Berkeley, California, to 601 Sheldon Building (461 Market Street), San Francisco. Region IV includes ECW activities at national parks and monuments and also at state and local parks in the states of California, Oregon, Washington, Nevada, Utah, Idaho, and Glacier Park in Montana. The geologic staff of Region IV includes also Walter M. Chappell and Bruno C. Petsch, assistant geologists with headquarters at the regional office in San Francisco, and Donald K. Mackay, associate geologist, with headquarters at the district office, 712 Spalding Building, Portland, Oregon.

C. MAYNARD BOOS is with the Independent Exploration Company, Esperson Building, Houston, Texas.

HARRY W. BELL, recently with the Lion Oil and Refining Company of El Dorado, Arkansas, is engineer for the Rodessa Operators' Committee of which P. C. MURPHY of the Phillips Petroleum Company is chairman.

SHEPARD W. LOWMAN has left the Mid-Continent Petroleum Corporation at Tulsa, Oklahoma, to accept a position in the geological department of the Shell Petroleum Corporation at Houston, Texas.

MARGARET F. BOOS heads a new department of geology at Denver University this year, where courses in geology and geography are being introduced.

JOHN L. RICH, of the geological faculty at the University of Cincinnati, has been in Kansas the past summer, extending productive shoe-string sands.

M. T. HARTWELL, geologist for The Texas Company, has been transferred from Wichita Falls to Fort Worth, Texas.

In connection with the search for petroleum, the Australian Commonwealth Government has voted the sum of £250,000 to assist in the search by the granting of pound-for-pound subsidies to companies engaged in drilling for oil under approved conditions. This fund is controlled by a committee of three Ministers of Cabinet, advised by a technical committee consisting of W. G. WOOLNOUGH as executive officer, L. KEITH WARD, Director of Mines of South Australia, and ARTHUR WADE, petroleum geologist.

FRANK REEVES, recently associated with D. DALE CONDIT of Oil Search Ltd., has returned to the United States after an extended study of geological conditions for oil and gas production in Australia.

JOHN M. ALDEN, district supervisor, oil and gas leasing division of the United States Geological Survey, at Tulsa, Oklahoma, now directs the drilling, producing, and marketing of oil and gas on all Government, including Indian, lands in the Mid-Continent supervisory district. Branch offices are maintained in Oklahoma City, Oklahoma, Wichita Falls, Texas, and Roswell, New Mexico.

The Geological Society of New Mexico, Roswell, New Mexico, has elected the following officers: GEORGE KROENLIN, president; HAL S. CAVE, vice-president; W. E. COX, secretary; and FRANK COUNSELMAN, treasurer.

V. R. GARFIAS, who for several years has been in charge of the Foreign Oil Department of the Cities Service interests, has been made a director of Cities Service Company.

The thirteenth annual meeting of the Pacific Section of the Association will be held at the Biltmore Hotel in Los Angeles on November 5 and 6. L. N. WATERFALL is chairman of the program committee. Technical sessions will be held from 9 A.M. to 12 noon and from 2 P.M. to 4 P.M. There will be informal luncheons at noon on Thursday and Friday and a dinner dance Friday evening. CHESTER CASSEL of The Texas Company is president of the Pacific Section and R. G. REESE of the Standard Oil Company is secretary-treasurer.

SOCIETIES

TEXAS

DALLAS PETROLEUM GEOLOGISTS
DALLAS, TEXAS

President - - - - - - - - - H. J. Hawley
The California Company

Vice-President - - - - - Charles B. Carpenter
U. S. Bureau of Mines

Secretary-Treasurer - - - - - - - R. A. Stehr
Texas Seaboard Oil Company

Meetings will be announced.

HOUSTON GEOLOGICAL SOCIETY
HOUSTON, TEXAS

President - - - - - - - - Phil F. Martyn
Houston Oil Company of Texas

Vice-President - - - - - - - - O. L. Brace
813 Second National Bank Building

Secretary-Treasurer - - Wallace C. Thompson
General Crude Oil Company, Esperson Building

Regular meetings, every Thursday at noon (12:15) at the Houston Club. Frequent special meetings called by the executive committee. For any particulars pertaining to meetings call the secretary.

EAST TEXAS GEOLOGICAL SOCIETY
TYLER, TEXAS

President - - - - - - H. J. McLellan
Humble Oil and Refining Company

Vice-President - - - - - J. W. Kisling, Jr.
Amerada Petroleum Corporation

Secretary-Treasurer - - - George W. Pirtle
Hudnall and Pirtle, Consulting Geologists

Meetings: Monthly and by call.

Luncheons: Every Friday, Cameron's Cafeteria.

FORT WORTH GEOLOGICAL SOCIETY
FORT WORTH, TEXAS

President - - - - - Norman L. Thomas
The Pure Oil Company

Vice-President - - - - - - J. F. Hosterman
Amerada Petroleum Corporation

Secretary-Treasurer - - - - Paul C. Dean
1818 W. T. Waggoner Building

Meetings: Luncheon at noon, Worth Hotel, every Monday. Special meetings called by executive committee. Visiting geologists are welcome to all meetings.

NORTH TEXAS GEOLOGICAL SOCIETY
WICHITA FALLS, TEXAS

President - - - - - - - - - Tom L. Coleman
United States Geological Survey

Vice-President - - - - - - - - Robert Roth
Humble Oil and Refining Company

Secretary-Treasurer - - - - - S. G. Waggoner
2013 Brown Street

Meetings: Second Friday, each month, at 6:30 P.M.
Luncheons: Fourth Friday, each month, at 12:15 P.M.
Place: Hamilton Building

WEST TEXAS GEOLOGICAL SOCIETY
SAN ANGELO AND MIDLAND, TEXAS

President - - - - - - - E. Russell Lloyd
Box 1106, Midland

Vice-President - - - - - - - P. D. Moore
Consulting Geologist, San Angelo

Secretary-Treasurer - - - - - M. B. Arick
Humble Oil and Refining Company, Midland

Meetings will be announced

WEST VIRGINIA

THE APPALACHIAN GEOLOGICAL SOCIETY
CHARLESTON, WEST VIRGINIA

President - - - - - - J. E. Billingsley
Commonwealth Gas Corporation
401 Union Building

Vice-President - - - - Charles E. Krebs
Consulting Geologist and Engineer

Secretary-Treasurer - - - Robert C. Lafferty
Owens-Libbey-Owens Gas Department, Box 1375

Meetings: Second Monday, each month, at 6:30 P.M., Ruffner Hotel.


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